WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

MARCH 1956

VOL. 33 No. 3 · SIX SHILLINGS

Including Index to Abstracts and References 1955

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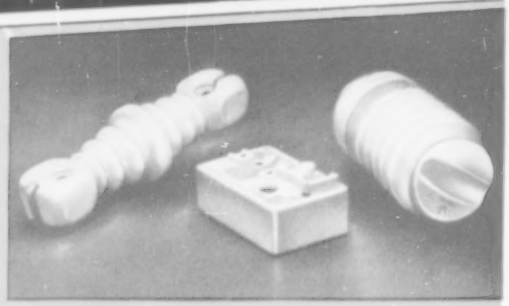

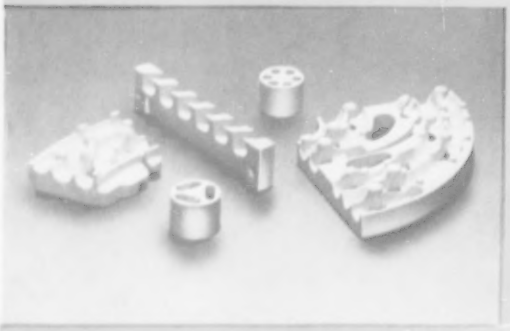

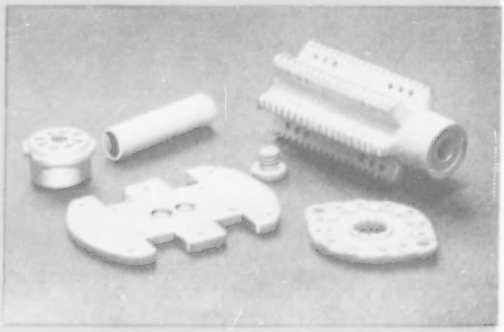

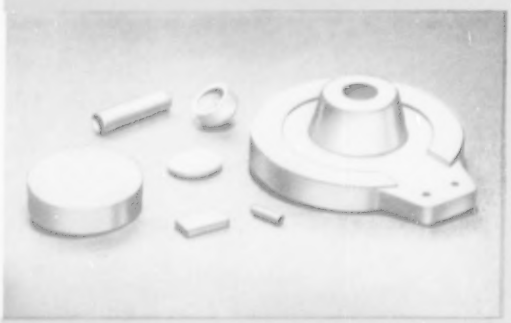

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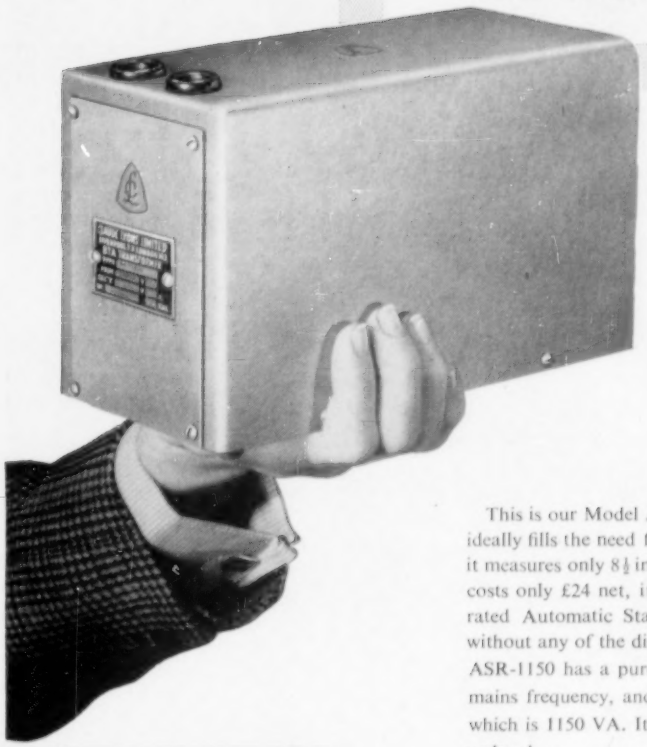
8(113)

A NEW-PRINCIPLE A-C AUTOMATIC VOLTAGE STABILISER



This is our Model ASR-1150 Automatic Voltage Step Regulator. It ideally fills the need for a cheap, small and light Stabiliser. Although it measures only 8½ in. × 4½ in. × 5 in., weighs as little as 11 lb., and costs only £24 net, it has a performance fully equal to any similarly rated Automatic Stabiliser of the resonated, saturated core type, without any of the disadvantages.

ASR-1150 has a pure output waveform, is unaffected by changes in mains frequency, and works equally well from no-load to full load, which is 1150 VA. It has a stabilised output at 230V unless otherwise ordered.

Many other Automatic Voltage Stabilisers are now manufactured by us, and all are available for immediate delivery. In some cases the constancy of output is as high as 0.15%. Models are available from 200 VA to 30 kVA, single phase. 3-Phase Stabilisers are also available. Prices are *extremely* competitive.

We can supply from stock all types of American tubes, condensers, valves, potentiometers, etc.

MEMO: If you are interested in infinitely-variable Transformers, do not forget the almost indispensable "VARIAC" (Reg'd. Trademark). Models are available from 170VA to 21kVA. Our Catalogue V-549 (3rd Edition) tells the whole story and will gladly be mailed free and post free, on request.

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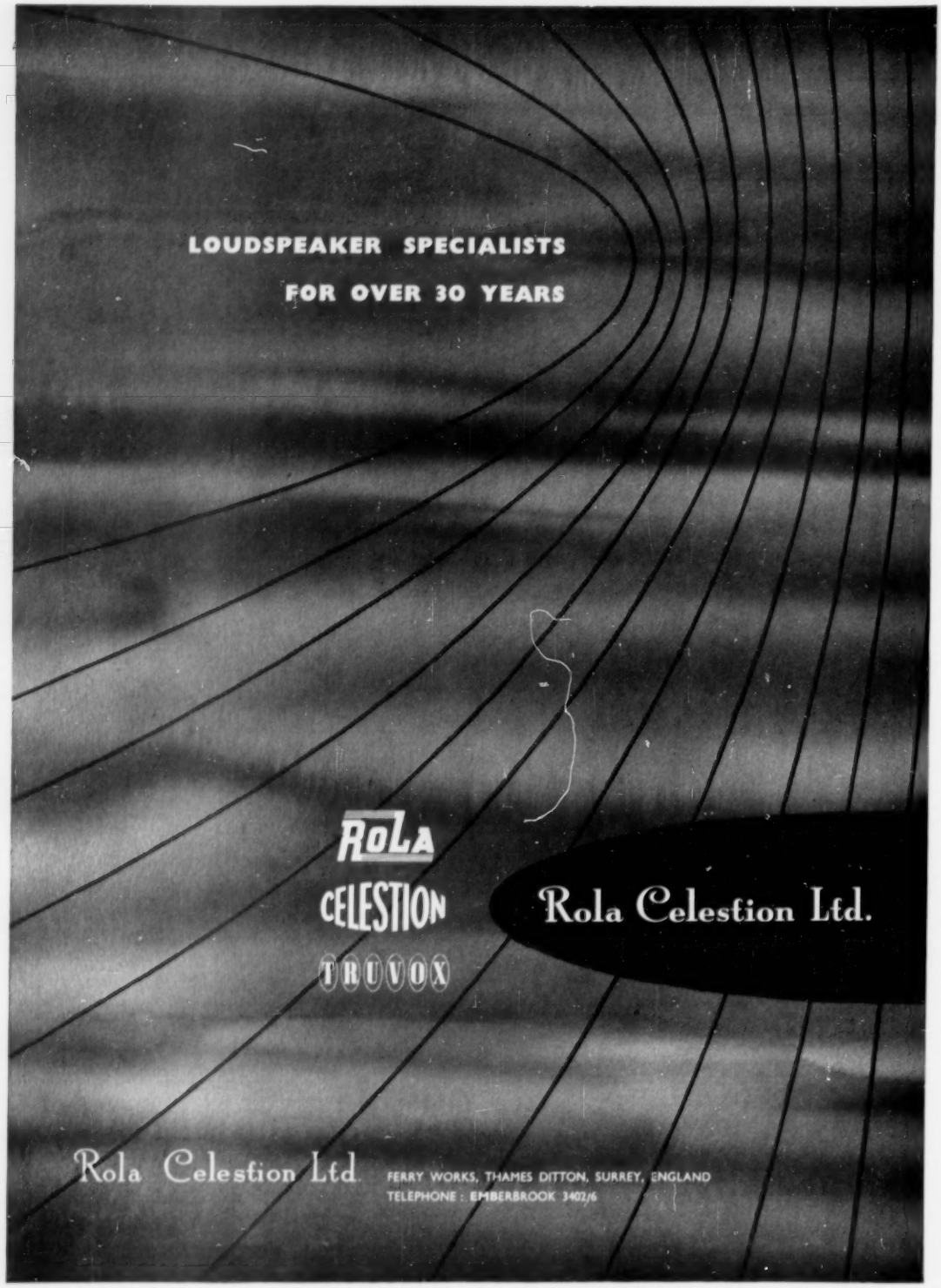
SOUTHERN FACTORY: VALLEY WORKS, WARE ROAD, HODDESDON, HERTS.
(A10 main London/Cambridge Road, at Junction of A602)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MORE POWER for your planning

To know about the Plessey 100-Watt Type XC227 Vibrator and its superiority for certain electronic applications, is to add strength to your future planning. When compared with a conventional rotary transformer, the 100-Watt Vibrator has numerous advantages. It is lighter. It is more compact. It offers a reduction in noise, improvement in circuit flexibility and increased efficiency which can be as high as 65% against the average of 40% from a rotary transformer. Voltage Regulating Relay—Type XI by Plessey, is complementary to the 100-Watt Vibrator and is designed to reduce substantially the variations of voltage supplies to radio or electronic equipment. Both are subjects of Plessey Publications—No. 732 and No. 769/1 respectively—which are available to design engineers on request.

Plessey 100-Watt Heavy Duty Vibrator

Developed in conjunction with S.R.D.E.

Specification

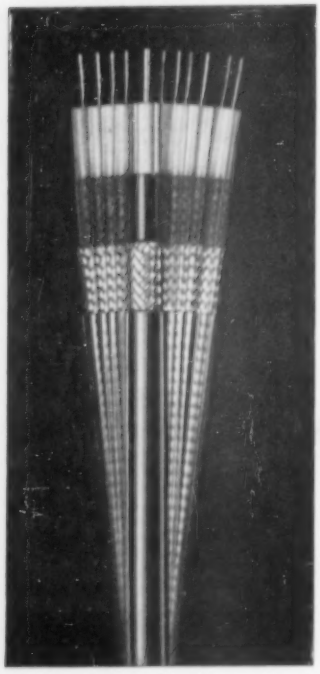
Operating Voltage	24v. nominal*
Operating Frequency	110 c/s nominal
Drive Coil Power	5 watts max.
Contact Closure	
Primaries	72%—84%
Secondaries	62%—74%
Working Life	1,000 hrs. nominal at 20° C. 500 hrs. nominal at 70° C.
Voltage Proof (at pressures down to 70 mm. Hg.)	750v. r.m.s. 50 c/s. between all parts not electrically connected.
Input Rating (24v. nominal supply)	5—8 amps.
Temperature Category	40/70 (— 40° C. to + 70° C.)
Humidity Class	H.1 meets requirements of R.C.S.172.
Bumping	Meets requirements of R.C.S.172.
Weight	12.6 oz.

* A 12-volt version of this vibrator is at present under test and will become available as soon as conditions of life and rating have been determined.

P.D. 1a

THE PLESSEY COMPANY LIMITED · ILFORD · ESSEX

non-microphonic cables



IT HAS BEEN ESTABLISHED that the flexing, vibrating, or knocking of small R.F. cables causes minute parasitic voltages to be generated. Where leads carrying small signals of the order of, say 10^{-10} amps are employed, the need to obviate this tendency is essential.

Telcon offer a range of cables having a Telcothene* insulant provided with a low-resistive covering adhering to the cable core immediately under the braid. With this construction it has proved possible to utilize the extremely good electrical and mechanical properties of Telcothene and at the same time reduce these troublesome parasitic voltages to a level lower by 20-50 db, compared with normal polythene cables.

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* Telcothene (Regd.) is polythene processed by Telcon to provide specific characteristics.

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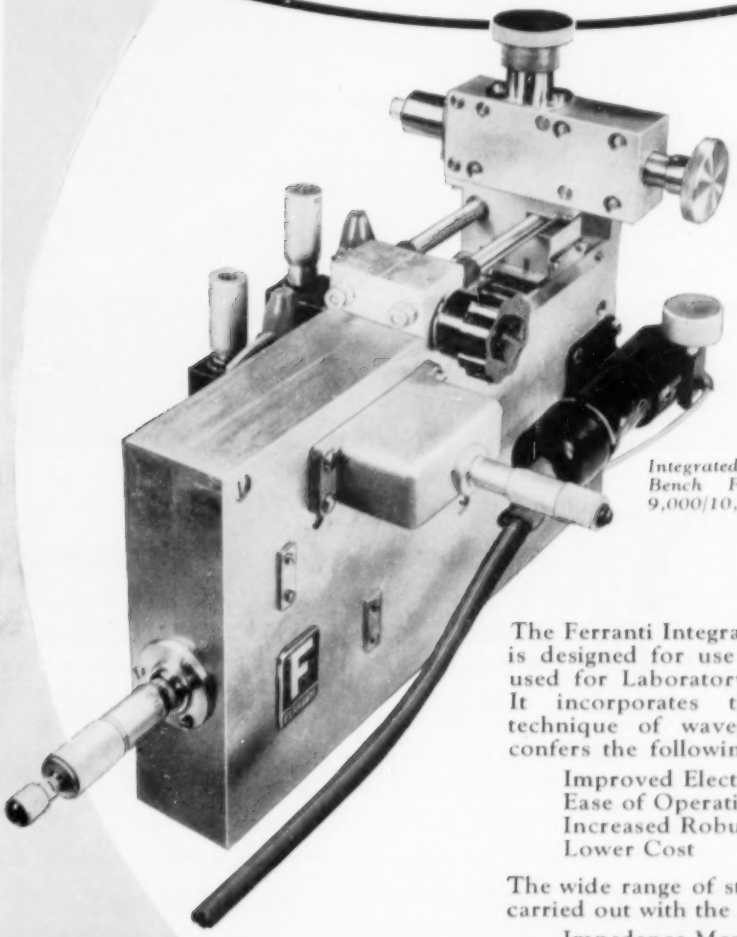

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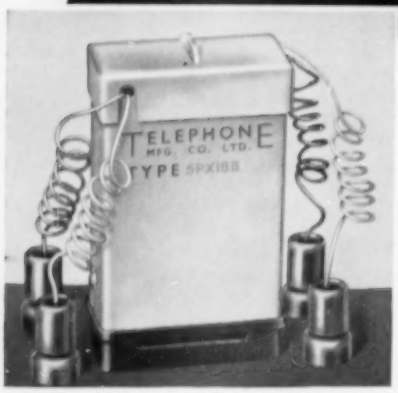
CARPENTER POLARIZED RELAYS



The Type 5PX Carpenter Polarised Relay is fitted with platinum contacts to reduce thermal noise, and has flying contact leads to reduce "pick-up" in contact circuit due to the coil. DIMENSIONS : *Height* 2.5 *in. Width* 1.6 *in. Depth* 0.8 *in. Approx. weight* 4.8 *oz.*

Simplify Recording, Control and Test circuits

The fast operating Carpenter Polarized Relay Type 5PX is being used very satisfactorily in a wide variety of control, recording and test circuits where the available initiating voltage is extremely low and must be greatly amplified before it can be used. The relay enables this to be done efficiently and economically by converting ("chopping") d.c. input signals to a square-wave alternating voltage which may then be amplified simply in an a.c. amplifier.

Alternatively, the small signal voltage can be fed to a straightforward d.c. valve amplifier, while a fraction of the voltage is taken to an a.c. amplifier using an " each-side-stable " Carpenter relay. One side-contact of the relay is used alternately to " earth " and to " free " this input voltage, thereby converting it to square-wave a.c., while the other side-contact demodulates the amplified a.c. output. This output is then fed back to the control grid of the original d.c. amplifier, thereby eliminating any tendency of the output to drift.

The Type 5PX relay has platinum contacts so that contact noise voltages are considerably reduced. Moreover, screening between coil and contact circuits—and flying contact leads, reduce to negligible proportions possible trouble due to " pick-up " from the coil. Where frequencies in excess of 50 c/s are required, specialized versions of the larger Type 3 relay can be used.

These " chopper " relays are successfully incorporated in laboratory test gear, supervisory circuits, temperature recorders, etc., and the Manufacturers will gladly make available to you their experience in this field of electronic equipment.

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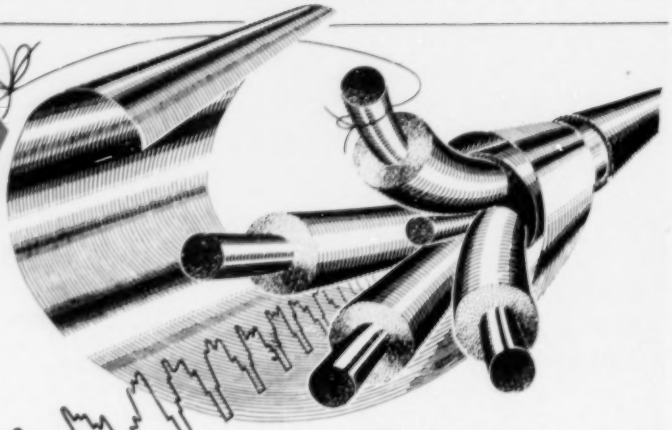

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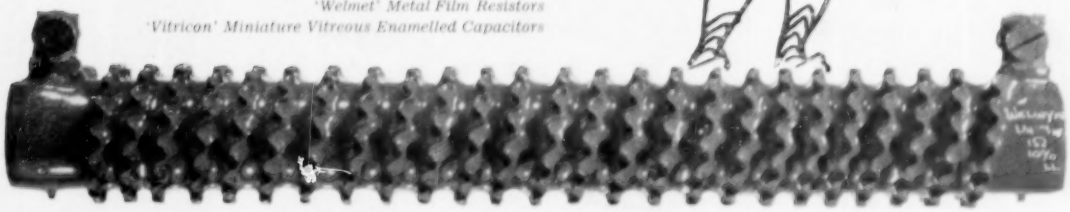

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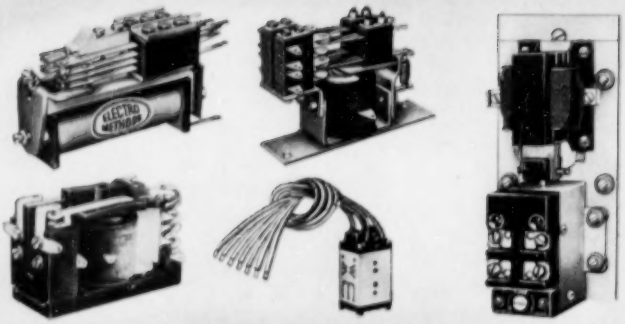

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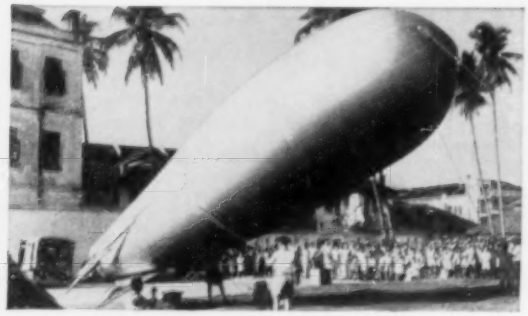

Marconi Surveying Service

LEFT. Balloon operations on the Ipoh-Telok Anson route in Malaya.

RIGHT. The mast is up and the motor generator is running during the survey of the Nigerian multi-channel system.

BELOW. The V.H.F. mobile survey team erect their mast.

Before planning any communication system, and particularly a microwave or V.H.F. multichannel system, a survey of the propagation conditions over the proposed path or area is essential. Similar, but less exhaustive surveys, are also necessary before planning V.H.F. mobile systems. Such surveys are undertaken by Marconi's, one of the very few radio manufacturers who do so. The teams engaged in the work may be called upon to operate in desert, swamp and jungle, over which line and cable routes would be impractical, on windswept moorlands or in densely populated city and suburban areas. Surveys are being, or have already been carried out all over the world, including: Uganda, Kenya, Tanganyika, Nigeria, Gold Coast, Tangier, Azores Norway, Turkey, Greece, Malaya, Ceylon, West Indies, Sweden, and also, of course, in Britain.

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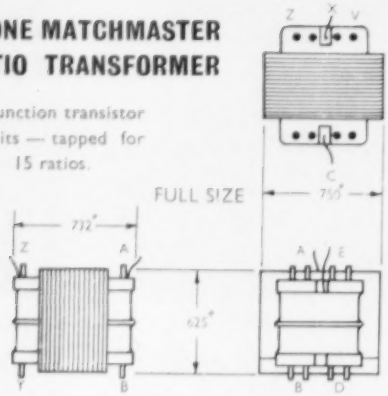

TYPE	primary induct.	P.E.R.	primary d.c. Ω	second d.c. Ω
MM-1A	15H at 0.4mA	170 kohms	350	150
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	1½	4	9
	2*	4½*	11
	2½	6	15
	3	7½	20

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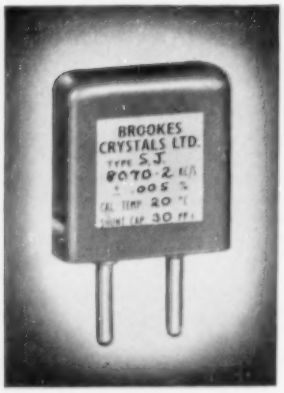

• *Illustrated above is a Type SJ Crystal Unit from a range covering 5-20 Mc/s and on the right is a Type SM Crystal Unit from a range covering 5-20 Mc/s.*

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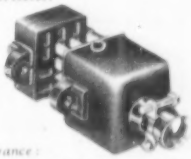
The Champs Elysees where at night the gaiety comes on with the lights and where when you know it all and want a new experience you can dive down the Argentine entrance to the Metro to say Le Cité Station to the island in the Seine on which stands Notre Dame and the floodlit San Michelé Fountain.



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- Contact tails flux dipped for ease of soldering in automatic assembly.
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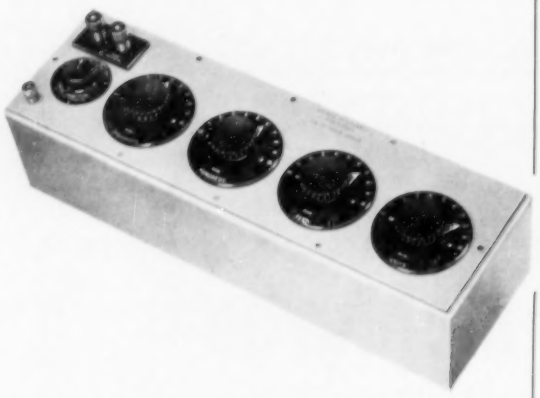

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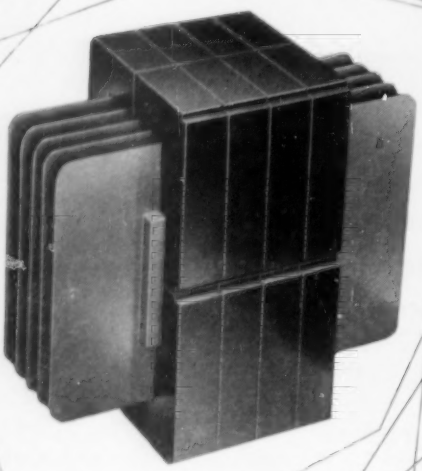

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Vol. 33 MARCH 1956 No. 3

The Electrostatic Loudspeaker Again

ELSEWHERE in this issue, we publish a letter referring to our May 1955 Editorial on the electrostatic loudspeaker. We there considered, among other things, the case of a conductive diaphragm, which is fed from a source of polarizing voltage through a resistance of such a high value that the total charge on the diaphragm cannot change during any signal excursion. We did not investigate this under signal conditions but calculated the static force on the diaphragm under constant-charge conditions as

$$F = \frac{2\kappa_0 A V^2}{d^2} \cdot \frac{x}{d}$$

Although we did not actually say so, we must admit that we rather implied that this force, due only to the position of the diaphragm, would be a distorting force under signal conditions. Since then, we have analysed the signal conditions and we agree with Mr. Nuttall that it is of the nature of a negative stiffness, and does not produce any non-linearity of response.

Referring to Fig. 1, a diaphragm D of negligible thickness carries a total charge of $2Q$ and is between two plates a distance $2d$ apart to which the signal voltage v_s is applied. When the diaphragm is displaced from the mid-point between A and B by the distance x there is separation of charge in the diaphragm so that one face bears $Q + q$ and the other $Q - q$.

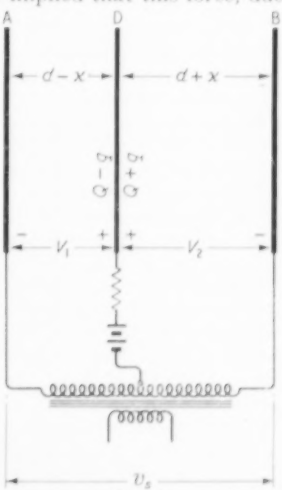

Fig. 1.

We assume that the diaphragm is positively charged. Potentials V_1 and V_2 must exist between it and the plates A and B and must be commensurate with the charges and the separations of the plates.

We can, consequently, write

$$Q + q = \frac{\kappa_0 A V_1}{d - x}; \quad Q - q = \frac{\kappa_0 A V_2}{d + x} \qquad \ldots \qquad (1)$$

where A is the area of the plates and κ_0 is the permittivity of free space, assuming the relative permittivity of air to be unity.

Around the closed loop formed by the signal source v_s and the plates forming the loudspeaker we have

$$0 = v_s + V_2 - V_1 \qquad \ldots \qquad \ldots \qquad \ldots \qquad (2)$$

From these three equations we can eliminate q and compute V_1 and V_2 in terms of x and v_s as the only variables.

Now between D and A there is a force F_1, tending to move D to the left, and between D and B a force F_2, tending to move D to the right. The resultant is

$$F = F_1 - F_2 = \frac{\kappa_0 A V_1^2}{2(d - x)^2} - \frac{\kappa_0 A V_2^2}{2(d + x)^2}$$
$$= \frac{2Q^2}{\kappa_0 A} \cdot \frac{x}{d} + \frac{Q v_s}{d} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (3)$$

on substituting the values of V_1 and V_2 derived from (1) and (2).

Let us now assume that the properties of the diaphragm with its air loading can be represented by the equation of motion

$$F = (p^2m + p\rho + S)x \qquad .. \qquad .. \qquad (4)$$

where $p = d/dt$, m = mass, ρ = total 'resistance', S = stiffness. This equation may seem unfamiliar, but that is due to the p-notation; it should be remembered that $px = dx/dt$ is the velocity of the diaphragm.

If we now combine (3) and (4) to eliminate force we get

$$v_s = \frac{d}{Q}\left[p^2m + p\rho + S - 2Q^2/\kappa_0 Ad\right]x \qquad (5)$$

This shows clearly that the term $2Q^2x/\kappa_0 Ad$ of (3) is of the nature of a negative stiffness. It represents the force due to the charge on the diaphragm and is opposed by the stiffness of the mounting of the diaphragm.

It is of interest to determine the signal current i which flows as a result of applying v_s. When the diaphragm moves, a charge q is displaced from one side to the other. When, as in Fig. 1 the charge is $-q$ on the left of D and $+q$ on the right, there must also be charges $+q$ on A and $-q$ on B. The movement of charge from one face of D to the other as D moves, thus produces an equal movement of charge between A and B through the signal source and the rate of change of this charge constitutes the signal current. From (1), (2) and (3)

$$q = \frac{Qx}{d} + \frac{\kappa_0 A}{2d}\,v_s$$

and

$$i = \frac{dq}{dt} = pq$$

$$= \frac{Q}{d}\,px + \frac{\kappa_0 A}{2d}\,pv_s$$

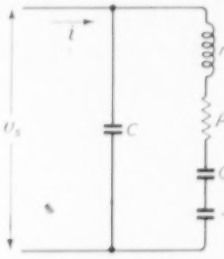

Fig. 2.

It is convenient to let $\kappa_0 A/2d = C$. Physically, it is the direct capacitance between A and B. We then have, substituting for v_s

$$i = \frac{Q}{d}\cdot px\left[1 + C\frac{d^2}{Q^2}\left\{p^2m + p\rho + S - Q^2/Cd^2\right\}\right]$$

$$.. \qquad .. \qquad (6)$$

and the admittance is

$$Y = \frac{i}{v_s} = pC + \frac{1}{\dfrac{d^2}{Q^2}\left(pm + \rho + S/p\right) - 1/pC} \qquad (7)$$

This equation is at once recognizable as one which can represent a capacitance C in shunt with a series resonant circuit and so an equivalent circuit for the loudspeaker is of the form shown in Fig. 2. The mechanical constants of the diaphragm are represented by inductance md^2/Q^2, resistance $\rho d^2/Q^2$ and capacitance Q^2/d^2S, while the electrical constants are represented by the shunt capacitance C between the fixed plates of the loudspeaker and a negative capacitance of the same value in series with the diaphragm elements.

In deriving these equations, no assumptions about the waveforms of voltage, current or displacement have been made. In all cases, the steady-state sinusoidal response is obtainable merely by writing $p = j\omega$ in the equations.

Under the conditions considered, the electrostatic speaker is perfectly linear and can be represented by quite a simple equivalent circuit.

It is of interest to notice that, since the electrical equivalents of mass and stiffness depend on d^2/Q^2, their values effective in the equivalent circuit can be altered by changing Q, which is simply done in practice by varying the polarizing voltage. This does not change the frequency of series resonance of the diaphragm itself for the 'LC' product $(= md^2/Q^2 \times Q^2/d^2S = m/S)$ is independent of d^2/Q^2. However, it does alter the series resonance frequency of the whole circuit, for the negative capacitance is independent of Q. This frequency depends on

$$\frac{m/S}{1 - Q^2/d^2SC}$$

However, the parallel resonance of the circuit as a whole is unaffected, for the positive and negative capacitances are in series around the circuit and cancel out. The main effect of varying the polarizing voltage is thus on the 'L/C' ratio of the resonant branch of the equivalent circuit and so on the total impedance of the loudspeaker.

In its practical forms, the diaphragm of the electrostatic loudspeaker is now made of an insulator, not a conductor. Since no insulator is perfect, it can acquire charge if given sufficient time and so, in the static condition, its surfaces will carry similar charges to a conducting diaphragm.

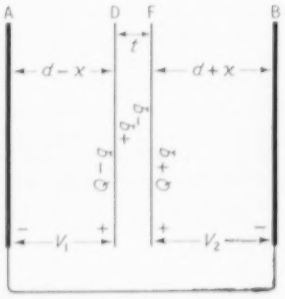

Fig. 3.

We may regard this diaphragm as being equivalent to one of a perfect insulator of relative permittivity κ_r and thickness t carrying conductive surfaces D and F, as in Fig. 3. Some straightforward, but tedious, calculation shows that under static conditions the

force is

$$F = \frac{2Q^2}{\kappa_0 A} \cdot \frac{x}{d} \cdot \frac{1}{1 + t/\kappa_r d}$$

If the equation quoted at the beginning for the static force on a conducting diaphragm is re-written in terms of Q, it will be found to equal the first terms of this equation. The law of variation of F with x is, therefore, unchanged but the magnitude of the force is altered. It is reduced with the insulating diaphragm.

We have not considered this case any further. It would not be difficult to work out the signal conditions on the same lines as we have done for the conducting diaphragm. It does involve some rather laborious algebra, however, and it may not be worth while to do it, for we feel some doubt about whether it does truly represent the insulating diaphragm in practice.

As we showed in the May 1955 Editorial, the internal time constant is adequate to keep the dynamic conditions close to those of a perfect insulator, but this does pre-suppose that the charge distribution over the surface of an insulator can be regarded as the same thing as the same charge in a conducting surface. For it to be the same, we must suppose that within a thin, almost surface, layer of the material, it is possible to have an almost instantaneous movement of charge to simulate the redistribution of charge in a conducting surface.

It is, of course, open to anyone to suppose that in practice there is always a sufficient layer of moisture over the surface to make the diaphragm really an insulator with conducting surfaces. This will certainly happen on occasion, but we doubt if it is always the explanation of what goes on.

W.T.C.

PARABOLIC CYLINDER AERIALS

By K. Foster, M.A.

(A. C. Cossor, Ltd., London)

SUMMARY.—For centimetric aerials with large beam-width ratios (greater than about 8:1) it is impracticable to use a paraboloidal reflector with a single horn feed. A reflector in the form of a parabolic cylinder has been suggested for this purpose and its focusing properties and performance have been discussed in the literature. In this paper, consideration is given to the details of the broad radiation pattern of the parabolic-cylinder type of aerial. An approximate theory is developed which yields the beam-widths and general shapes of these patterns and design criteria are established. Comparison with published figures show that the theory is accurate enough for practical design purposes.

Introduction

IT is often required that a radar aerial shall have a large ratio of beam-widths (greater than about 8:1) in two orthogonal planes, which are usually vertical and horizontal. An example of this occurs, for instance, in the case of shipborne radars where the rolling of the ship produces difficulties if the vertical beam-width of the aerial is small. Consequently, unless the designer resorts to mechanical stabilization, the vertical beam-width of a shipborne aerial must be made large enough to nullify the effects of rolling. Since many such radars are used to detect the presence of surface obstacles, the resultant loss of discrimination in the vertical plane can often be accepted. Thus the vertical beam-width may be of the order of 20° whereas the horizontal beam-width (which must be small to maintain the required azimuthal discrimination) may be of the order of 1° to 2°. The aerial designer, therefore, is led to beam-width ratios of between 10:1 and 20:1. These large ratios create serious difficulties if a normal paraboloidal reflector with a single feed-horn is envisaged. As an example of these difficulties the case can be considered for which a vertical-to-horizontal beam-width ratio of 16:1 is required. For a paraboloidal reflector, the ratio of beam-widths obtained is roughly given by the inverse ratio of the respective reflector aperture dimensions and, hence, in the example quoted the ratio of horizontal-to-vertical aperture dimensions must be about 16:1. Furthermore, it is not advisable, for reasons of good aerial gain and sidelobe performance, to make the focal length of the reflector less than one quarter of the broad dimension of the reflector (and, in fact, it is better to have a greater focal length than this). This means that the ratio of focal length to vertical aperture must be at least 4:1 in the case above and, since the horn feed at the focus concentrates the radiated power into the reflector, it can be shown that the vertical beam-width required from the horn is of the order of 14°, a value which, if not impossible, is usually impracticable.

Various types of aerials have been proposed for this purpose[1] one of the best using a reflector in the form of a parabolic cylinder fed by a single feed horn. The performance of this type of aerial has been discussed in the literature[2,3] and the focusing properties of the parabolic cylinder have

MS accepted by the Editor, March 1955

been considered. However, no attention appears to have been given to the form of the vertical (broad) pattern and it is the purpose of this paper to derive the necessary information from which the length of the cylinder (that is to say, the vertical aperture of the reflector) can be obtained. The formation of the horizontal (narrow) pattern, the choice of horizontal aperture and focal length are governed by much the same criteria as those found for paraboloidal reflectors.

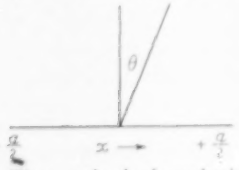

Fig. 1. *Co-ordinate system of line source of length 'a'.*

The method of analysis assumes that the aperture phase distribution for a parabolic-cylinder reflector follows a square law in the vertical direction and is constant in the horizontal direction[3]. (The use of the words vertical and horizontal here is convenient as, in practice, the parabolic cylinder usually has its generators near vertical and intercepts of the cylinder with horizontal planes are parabolic curves.) Consequently the main details of the vertical-radiation pattern of this type of reflector can be derived by consideration of the radiation pattern of a line source with a square-law phase distribution. The general form of the expression used to determine this radiation pattern [designated here by $g(\theta)$] is

$$g(\theta) = \int_{-a/2}^{+a/2} F(x) \exp. \left\{ j \frac{2\pi x}{\lambda} \sin \theta \right\} dx \quad .. \quad (1)$$

where the co-ordinate system is as shown in Fig. 1, a is the total length of the line source, $F(x)$ is a function representing the field distribution along the line source and λ is the wavelength. It should be noted that this integral is, strictly speaking, only true for a constant phase distribution and even then only for narrow beam-widths. In all cases used here, however, the correction term is small enough to be neglected, since only the structure of the main beam of the radiation pattern will be considered. The details of this structure will be dealt with in the following two sections for the two cases of constant- and cosinusoidal-amplitude distributions respectively. In the final section the relationship of this analysis to parabolic-cylinder reflector design is considered.

Constant-Amplitude Distribution

The field distribution $F(x)$ will be taken in this section to be of the form

$$F(x) = \exp. j\phi(x)$$

with

$$\phi(x) = (x/2a)^2 \Phi \quad .. \quad .. \quad .. \quad (2)$$

Use of equation (1) then yields the radiation pattern as

$$g(\theta) = \int_{-a/2}^{+a/2} \exp. j \left\{ (x/2a)^2 \Phi - \frac{2\pi x}{\lambda} \sin \theta \right\} dx \quad (3)$$

This equation can be simplified somewhat by making the substitutions

$$\alpha = \frac{\pi a}{\lambda} \sin \theta$$

$$\nu = \sqrt{\frac{2\Phi}{\pi}} \left\{ \frac{2x}{a} - \frac{\alpha}{2\Phi} \right\} \quad .. \quad .. \quad (4)$$

Writing it as a function of α rather than θ, the radiation pattern is then given by

$$g(\alpha) = \frac{a}{2} \sqrt{\frac{\pi}{2\Phi}} \exp. \left\{ -j \frac{\alpha^2}{4\Phi} \right\} \int_{-\nu_1}^{+\nu_2} \exp. \left\{ j \frac{\pi \nu^2}{2} \right\} d\nu \quad .. \quad .. \quad .. \quad (5)$$

where the limits of integration are

$$\nu_1 = \sqrt{\frac{2\Phi}{\pi}} \left\{ 1 + \frac{\alpha}{2\Phi} \right\}$$

$$\nu_2 = \sqrt{\frac{2\Phi}{\pi}} \left\{ 1 - \frac{\alpha}{2\Phi} \right\}$$

The integral involved in equation (5) is the Fresnel integral and can be evaluated either from tables or from the Cornu spiral. It is not necessary, however, to compute $g(\alpha)$ to find the broad features of the pattern. Let the integral be rewritten as

$$\int_0^{\nu_1} \exp. \left\{ j \frac{\pi \nu^2}{2} \right\} d\nu + \int_0^{\nu_2} \exp. \left\{ j \frac{\pi \nu^2}{2} \right\} d\nu$$

and consider the Cornu spiral, one half of which is shown in Fig. 2. Each of the integrals above can be represented as a suitable vector as shown in Fig. 2 and $g(\alpha)$ is proportional to the resultant of these two vectors [neglecting the phase term in equation (5)]. When $\alpha = 0$, $\nu_1 = \nu_2 = \sqrt{2\Phi/\pi}$

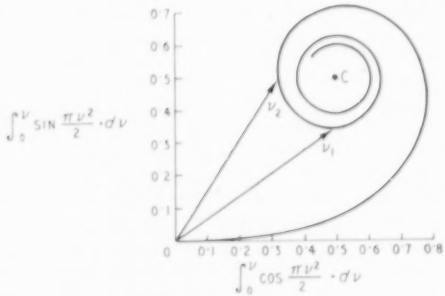

Fig. 2. *One half of Cornu spiral.*

and as α increases, the point ν_1 will move in an anticlockwise direction and the point ν_2 will move in a clockwise direction around the spiral. Thus, as long as ν_1 and ν_2 are large enough (note that

ν is the path length on the spiral from the origin) the resultant of the two vectors will oscillate about 2OC.

As α increases ν_2 decreases and thus, if α is large enough to make ν_2 vanish, only one vector will remain. This value of α is the value which gives the approximate half-field-strength width of the radiation pattern. From the equation defining ν_2, the value of α required, denoted by α_v, is

$$\alpha_v = 2\Phi \qquad (6)$$

The condition for this to be valid is approximately given by

$$\nu(\alpha = 0) > \sqrt{2} \text{ or } \Phi > \pi \qquad (7)$$

The value of α_v obtained from equation (6) can be compared with the value of α obtained for the equivalent constant phase source which is given approximately by $\alpha'_v = 0{\cdot}6\pi$. The ratio of these two will be called the broadening factor and denoted by μ which is given by

$$\mu = \frac{\alpha_v}{\alpha'_v} = \frac{3{\cdot}3\Phi}{\pi} \qquad (8)$$

To confirm the above formulae the patterns were calculated for several values of Φ and are shown in Fig. 3. (The decrease with increasing Φ due to the term $\sqrt{\pi/2\Phi}$ has been ignored in these curves.) From these the values of the broadening factor were calculated and are presented for comparison with equation (8) in Fig. 4. Values of μ for $\Phi > \pi$ are difficult to determine with accuracy due to the complexity of the patterns. They have therefore been calculated using the values of α for which the field strength has an amplitude of OC (see Fig. 2).

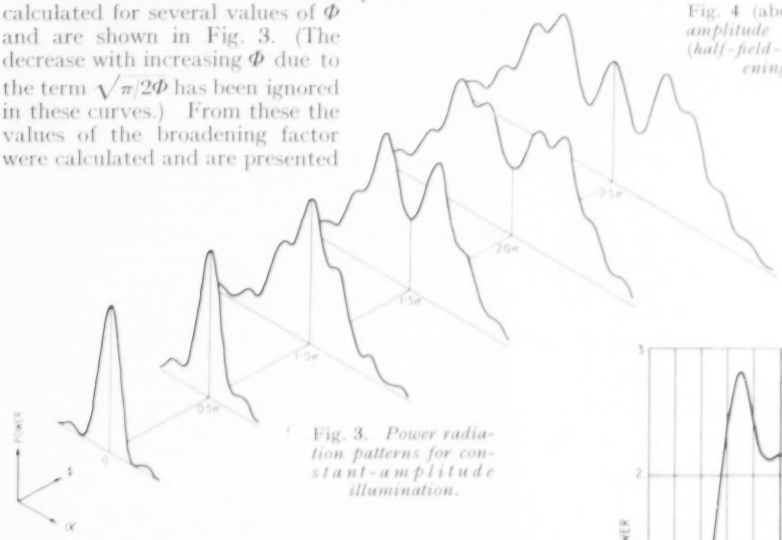

Fig. 3. *Power radiation patterns for constant-amplitude illumination.*

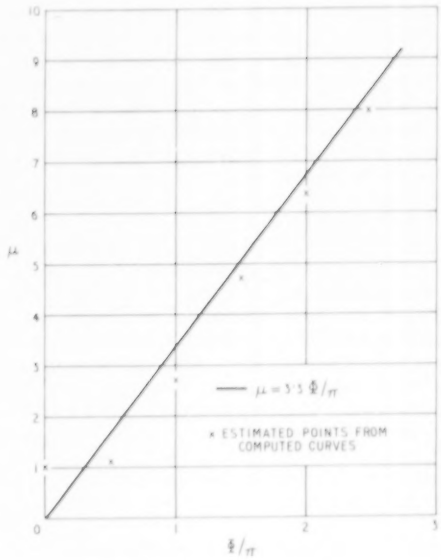

Fig. 4 (above). *Constant-amplitude illumination (half-field-strength broadening factor).*

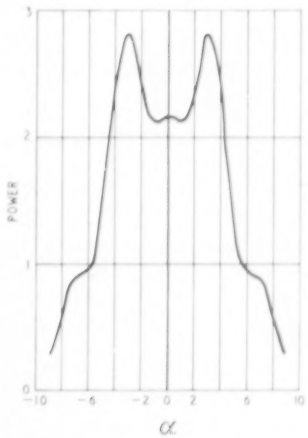

Fig. 5. *Power pattern for* $\Phi = 1{\cdot}28\pi$.

It would appear from Fig. 3 that for certain values of Φ the radiation pattern should be reasonably flat-topped (for instance one value should lie between $1{\cdot}0\pi$ and $1{\cdot}5\pi$). These values can be derived approximately by consideration of

the Cornu spiral and the two vectors. Since these two vectors have a common starting point and their end-points move in opposite directions around the spiral the pattern is likely to be flattest if the amplitude of one vector increases when the amplitude of the other decreases. While this cannot be ensured throughout the pattern a good approximation, especially near the centre of the pattern, is obtained for starting points lying in a line through C perpendicular to OC. The first of these points which satisfies the inequality (7) is the point $\Phi = 1{\cdot}28\pi$ (*cf.* reference 3) and the pattern for this is shown in Fig. 5. This particular pattern is not very flat since it is for the first of the points, but it does show the tendency for the centre undulations to be ironed out leaving only the side peaks. Even here, however, there is an improvement over the patterns for $1{\cdot}5\pi$, $2{\cdot}0\pi$, and $2{\cdot}5\pi$, in which the troughs amount to almost half the peak value. The side peaks are a natural consequence of the widening of the Cornu spiral for small values of ν.

Cosinusoidal-Amplitude Distribution

In this section the field distribution function $F(x)$ is assumed to taper in amplitude to zero at the ends of the line source but to maintain, as before, a square-law phase distribution. The substitution to be made into equation (1) is now

$$F(x) = \cos\frac{\pi x}{a}\exp.\, j\phi(x)$$

with

$$\phi(x) = (x/2a)^2\Phi \qquad .. \quad .. \quad .. \qquad (9)$$

The radiation pattern is thus given by

$$\begin{aligned} g(\theta) &= \int_{-a/2}^{+a/2}\cos\frac{\pi x}{a}\exp.\, j\left\{(x/2a)^2\Phi - \frac{2\pi x}{\lambda}\sin\theta\right\}dx \\ &= \frac{1}{2}\int_{-a/2}^{+a/2}\exp.\, j\left\{(x/2a)^2\Phi - \frac{2\pi x}{\lambda}\sin\theta + \frac{\pi x}{a}\right\}dx \\ &\quad + \frac{1}{2}\int_{-a/2}^{+a/2}\exp.\, j\left\{(x/2a)^2\Phi - \frac{2\pi x}{\lambda}\sin\theta - \frac{\pi x}{a}\right\}dx \\ &\qquad .. \quad .. \quad .. \qquad (10) \end{aligned}$$

This equation can be simplified as before, by making the substitutions

$$\left.\begin{aligned} \alpha &= \frac{\pi a}{\lambda}\sin\theta \\ \nu &= \sqrt{\frac{2\Phi}{\pi}}\left\{\frac{2x}{a} - \frac{\alpha - \pi/2}{2\Phi}\right\} \text{ in the first integral of (10)} \\ \nu &= \sqrt{\frac{2\Phi}{\pi}}\left\{\frac{2x}{a} - \frac{\alpha + \pi/2}{2\Phi}\right\} \text{ in the second integral of (10)} \end{aligned}\right\} \qquad (11)$$

After some rearrangement the expression for the radiation pattern becomes

$$g(\alpha) = \frac{a}{2}\sqrt{\frac{\pi}{2\Phi}}\exp.\left\{-j\frac{\alpha^2 + (\pi/2)^2}{4\Phi}\right\}\left[\exp.\left\{j\frac{\pi\alpha}{4\Phi}\right\}\int_{-\nu_4}^{+\nu_4}\exp.\left\{j\frac{\pi\nu^2}{2}\right\}d\nu + \exp.\left\{-j\frac{\pi\alpha}{4\Phi}\right\}\int_{-\nu_3}^{\nu_3}\exp.\left\{j\frac{\pi\nu^2}{2}\right\}d\nu\right]$$
$$.. \quad .. \quad .. \qquad (12)$$

where the limits of integration are given by

$$\left.\begin{aligned} \nu_1 &= \sqrt{\frac{2\Phi}{\pi}}\left\{1 + \frac{\alpha - \pi/2}{2\Phi}\right\} \\ \nu_2 &= \sqrt{\frac{2\Phi}{\pi}}\left\{1 - \frac{\alpha - \pi/2}{2\Phi}\right\} \\ \nu_3 &= \sqrt{\frac{2\Phi}{\pi}}\left\{1 + \frac{\alpha + \pi/2}{2\Phi}\right\} \\ \nu_4 &= \sqrt{\frac{2\Phi}{\pi}}\left\{1 - \frac{\alpha + \pi/2}{2\Phi}\right\} \end{aligned}\right\} \quad .. \quad .. \qquad (13)$$

The integrals involved in equation (12) can be written as before and represented as vectors as was done in Fig. 2. The system is more complicated than in the previous section and it is convenient to simplify the notation by defining

$$I(\nu) = \int_0^{\nu}\exp.\left\{j\frac{\pi\nu^2}{2}\right\}d\nu$$

It is clear from equation (12) that only the term in the brackets has any influence on the shape of the radiation pattern and it can be shown that the power-radiation pattern is proportional to

$$\left|\cos\frac{\pi\alpha}{4\Phi}\left\{I(\nu_1) + I(\nu_2) + I(\nu_3) + I(\nu_4)\right\} + j\sin\frac{\pi\alpha}{4\Phi}\left\{I(\nu_1) + I(\nu_2) - I(\nu_3) - I(\nu_4)\right\}\right|^2$$
$$.. \quad .. \quad .. \qquad (14)$$

Since all the integrals in (14) will oscillate, as α varies, about the complex value OC, provided that Φ is large enough, the second term in this expression will be small. By the same argument the sum of all four integrals in the first term will be substantially constant and, therefore, the dominant feature of the power pattern is the law $\cos^2(\pi\alpha/4\Phi)$. The value of α, for which this term is one half of its maximum value (the latter value being unity at $\alpha = 0$), is simply given by

$$\alpha_P = \Phi \qquad .. \quad .. \quad .. \qquad (15)$$

the quantity α_P designating the half-power beam-width of the radiation pattern. The first zeros of the dominant term occur for

$$\alpha_0 = 2\Phi \qquad .. \quad .. \quad .. \qquad (16)$$

although the actual pattern will not, in general, show these zeros, due to the presence of the second term in expression (14) which was neglected to obtain (15) and (16). As in the previous section, a broadening factor can be defined by comparing α_P

with the equivalent value for a constant-phase source, in this case given by $\alpha' p = 0{\cdot}6\pi$. The result for the cosinusoidal distribution is then

$$\mu = \frac{\alpha p}{\alpha' p} = \frac{1{\cdot}67\Phi}{\pi} \qquad (17)$$

It should be remembered that in the case of (17) the broadening factor relates to half-power values whereas in the case of (8) the values concerned are half-field-strength values.

In order to check the accuracy of equation (17) patterns were computed using expression (14). These patterns are shown in Fig. 6,

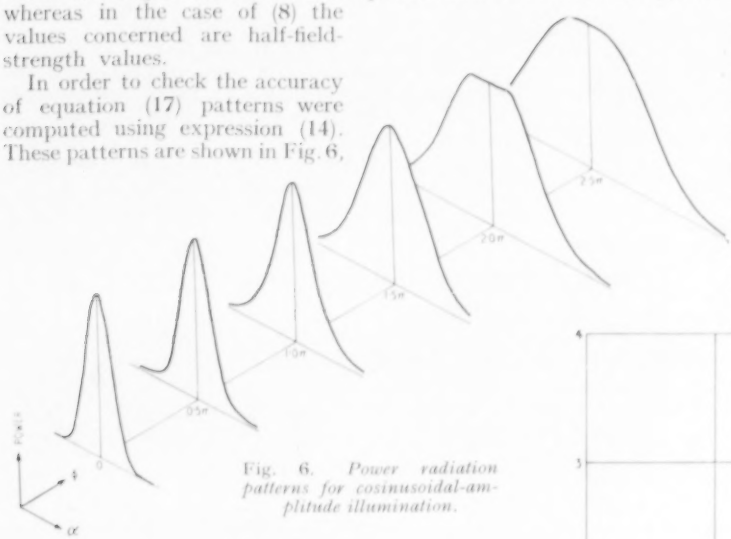

Fig. 6. *Power radiation patterns for cosinusoidal-amplitude illumination.*

and a comparison between (17) and the computed broadening factors is shown in Fig. 7. As before, the representation can be expected to hold for

$$\Phi \geqslant \pi \qquad (18)$$

There is a marked difference between these results and those of the previous section. First, the patterns show very little evidence of the violent undulations obtained in the constant-amplitude case. This is partly to be expected since four vectors are now employed in the summation instead of two. Fine structure is present, of course, and can be noticed on the pattern for $\Phi = 2{\cdot}0\pi$ as well as being responsible for the flat top of the curve for $\Phi = 2{\cdot}5\pi$. For the rest of the patterns slight undulations are obtained on the slopes of the curves when these are plotted on a decibel scale, but the scale of Fig. 6 is not sensitive enough to show these. Secondly, because of the absence of fine structure, the half-power values are more accurately determined and also the agreement with (16) is more marked, especially for the higher values of Φ.

A further insight into the behaviour of the four vectors in producing a smooth pattern can be obtained by the following argument. The main part of the Cornu spiral, as far as the centre section of the pattern is concerned, is almost a circle about the point C. An approximate representation of the situation can therefore be obtained as in Fig. 8 in which P_1 and P_2 are the two starting points at $\alpha = 0$. The resultant field-strength is the sum of the four vectors as shown and, due to (13), the end points of these vectors can be considered to be moving round the circle at approximately equal rates. Now it is clear that, if $\gamma_1 + \gamma_2 = \pi$, the resultant of the four vectors in this representation will be just 4(OC), which is independent of the angle β and hence of α. Thus the sum of the integrals in the first, and dominant, term of (14) is, under this condition, almost independent of α. This condition means that the two starting points lie on opposite

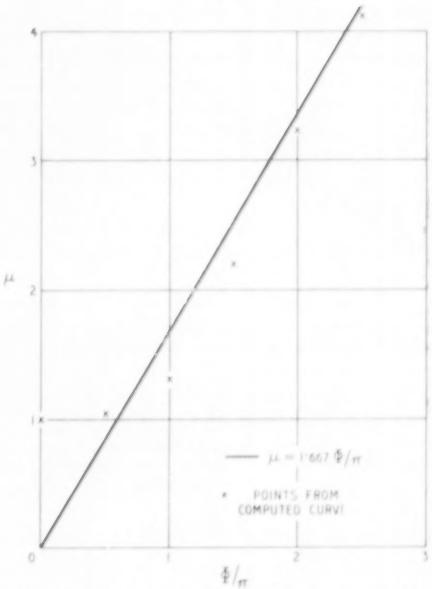

Fig. 7. *Cosinusoidal-amplitude illumination (half-power broadening factor).*

ends of a diameter through C. Consider now Table I in which are tabulated values of

TABLE I

Φ/π	v_{P1}	v_{P2}	v_{diam}
0·5	0·50	1·50	1·44
1·0	1·06	1·76	1·75
1·5	1·44	2·02	2·01
2·0	1·75	2·25	2·24
2·5	2·02	2·46	2·46

v_{P1}, v_{P2} and the value of v at the opposite end of the diameter Cv_{P1}.

It can be seen that, in fact, the two starting points very nearly satisfy the condition derived above, and thus in practice the sum of the integrals, which would form the main fine structure contribution to the centre of the pattern, is almost independent of α.

A final point to notice is that the broadening factor in this case is not so great as in the constant amplitude case. This behaviour would be expected due to the tapering of the amplitude distribution.

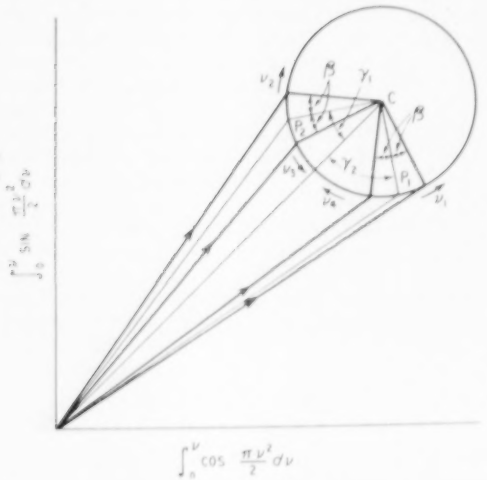

Fig. 8. *Approximate representation of the Cornu spiral valid for $v > \sqrt{2}$. The end points of the vectors are functions of the variable α [c.f. equation (13)]. If this parameter is zero, v_1 and v_4 coalesce to P_1, v_2 and v_3 coalesce to P_2. With increasing α these end points move round the circle in the directions indicated. The angle β is a measure of the distance moved, and its main use here is to emphasize the fact that, in this approximation, the four angles so labelled are equal.*

Application to Parabolic-Cylinder Aerials

In this section, the operation of the parabolic-cylinder aerial is discussed with relation to the preceding analysis. Since, in practice, the cosinusoidal-amplitude distribution is obtained across the reflector aperture rather than the constant distribution, the analysis in the last section will form the starting point.

A vertical cross-section of the aerial assembly is illustrated in Fig. 9. The line AB represents the reflector, f is the focal length of the horizontal parabola and there is a feed horn at F (the focus of this parabola) which will be assumed to have a sinusoidal distribution of field amplitude in the vertical plane. The vertical aperture of this horn is of such a length that ψ_0 is the first zero of the radiation pattern.

First of all, the relationship of the reflector pattern to the horn pattern can be formed. For the assumed sinusoidal distribution across the horn aperture the half-power level of the horn-radiation pattern occurs approximately at

$$\psi_P = \frac{0{\cdot}6}{1{\cdot}5}\psi_0 \qquad .. \quad .. \quad .. \quad (19)$$

and, since the resultant amplitude distribution across the reflector in the vertical plane is substantially of the form discussed in the previous section, the phase distribution being of square-law form, the half-power level of the reflector-radiation pattern can be obtained from equation (15) which can be written approximately as

$$\alpha_P \approx \frac{\pi a}{\lambda}\theta_P = \Phi$$

whence

$$\theta_P = \frac{\lambda\Phi}{\pi a} \qquad .. \quad .. \quad .. \quad (20)$$

Now, from the geometry of the system, it can be shown that

$$\psi_0 \approx \frac{a}{2f}$$

$$\Phi \approx \frac{2\pi}{\lambda}\cdot\frac{a^2}{8f} = \frac{\pi a^2}{4\lambda f} \qquad .. \quad .. \quad .. \quad (21)$$

and thus, using (19), (20) and (21), the half-power levels of the two radiation patterns are given by

$$\theta_P \approx a/4f$$
$$\psi_P \approx a/5f \qquad .. \quad .. \quad .. \quad (22)$$

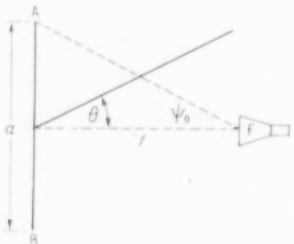

Fig. 9. *Vertical cross-section of aerial assembly.*

The relationship between these two angles is clearly

$$\theta_P \approx 1{\cdot}25\,\psi_P \qquad .. \quad .. \quad .. \quad (23)$$

This equation shows that the reflector substantially images the horn pattern although there is a slight broadening. It should be noted that, if the zeros of the patterns are considered [as defined for the reflector by (16)], the broadening is no longer obtained. The condition for equation (23) to hold is just that given by equation (18). Use of

equation (21) to write this condition in terms of the reflector geometry yields

$$\frac{a}{\lambda} \geqslant 2\sqrt{\frac{f}{\lambda}} \quad .. \quad .. \quad .. \quad (24)$$

and it can now be seen that the condition establishes a minimum vertical height for the reflector.

An alternative interpretation of the condition can be obtained by consideration of small values of a/λ; i.e., small compared with those involved in equation (24). For these values the phase distribution across the reflector aperture can be considered as constant and the half-power level is given by the normal relation

$$\theta_P \approx \frac{108}{\pi} \cdot \frac{\lambda}{a} \text{ degrees} \quad .. \quad .. \quad .. \quad (25)$$

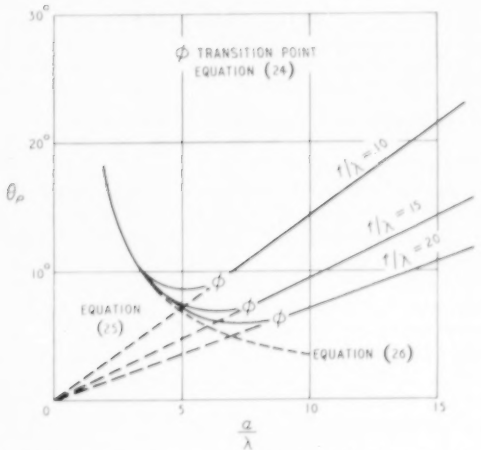

Fig. 10. *Plot of equations* (25) *and* (26). *The transition points indicate the region of changeover from a diffraction to a horn-image pattern.*

The first equation in (22) can be written as

$$\theta_P \approx \frac{45}{\pi} \cdot \frac{a}{\lambda} \cdot \frac{\lambda}{f} \text{ degrees} \quad .. \quad .. \quad (26)$$

which is valid under condition (24). If these last two equations are combined the curves of Fig. 10 can be drawn, on which are shown points corresponding to the limiting condition. These points represent a region of transition between a normal diffraction pattern and a horn-image pattern. These curves are also illuminating in that they show that for a given value of f/λ there is a minimum half-power beam-width which can be obtained using the parabolic-cylinder aerial.

Conclusion

In conclusion, the results of the last section can be compared with the vertical-radiation pattern published by Kiely[3] which shows an overall beam-width between the half-power points of about 18°. Based on the quoted dimensions the values to be inserted into equation (26) are

$$\frac{a}{\lambda} = 9{\cdot}62, \quad \frac{f}{\lambda} = 14{\cdot}44$$

and, since condition (24) is satisfied, the value of θ_P obtained should be valid. The beam-width between the half-power points (which, it should be noted, is $2\theta_P$) is then calculated as 19·04°, a value in fair agreement with that measured. Further, it can be seen from Fig. 7 that the approximate theory tends to over-estimate the broadening factor and this could account for part of the discrepancy. It would appear, therefore, that the approximations made in the preceding sections are accurate enough for most practical design details.

Acknowledgments

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In consequence of printing difficulties, publication of this issue of *Wireless Engineer* has been greatly delayed. Subsequent issues will appear at intervals of less than a month until the normal publication date can be resumed.

MICROWAVE VEHICLE-SPEED INDICATOR

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SUMMARY.—A new form of microwave vehicle-speed indicator† which has been developed at the Dominion Physical Laboratory for operational use by the New Zealand Transport Department is described.

It is much less complex than earlier forms of equipment using radar technique to measure speed as indicated by the Doppler frequency shift caused by a moving target. A hybrid waveguide junction is used to provide both transmitting and receiving channels so that only a single aerial is required, and by using the leakage between opposite arms of the junction the klystron oscillator, used as a c.w. transmitter, also provides local-oscillator power for the homodyne detection process employed. The complexity of a superheterodyne receiver, as used in earlier equipments, is removed.

The present operating wavelength is in the 3-cm region and, using an 18-in. diameter paraboloid reflector, ranges of several hundred yards on small modern cars are obtained.

A description of the initial circuit is given and the subsequent modifications following experimental trials. These include an automatic gain-control circuit which increases the sensitivity of the trigger circuits as the signal level increases. Various forms of indicator and recording methods are briefly considered, and the significance of the aerial beam-width is discussed in so far as coverage and siting problems are concerned.

The accuracy of the speed indication is discussed in the Appendix with an analysis of the errors arising throughout the equipment.

1. General

THE Doppler principle is well known and in the radar application it can be shown that, for a transmitter frequency f, the frequency of a signal received by reflection from a moving target is:—

$$f(1 \pm 2v/c)$$

where v is the radial velocity of the target and c is the velocity of e.m. waves.

The Doppler frequency shift which can be obtained by heterodyning the transmitted and received frequencies is

$$2vf/c$$

so that a circuit capable of measuring this frequency may be suitably calibrated and used to indicate the target velocity.

A difficulty in devising a practical system is that a detector sufficiently sensitive to detect the very small reflected signals (e.g., a silicon crystal) would be damaged if exposed directly to the comparatively high-level transmitter power. It has been the usual practice, therefore, to use separate transmitting and receiving aerials, so screened one from the other that only a small portion of transmitter power, sufficient for comparison purposes with the received power, leaks into the receiver aerial and thence to the detector. In addition, in an earlier model of a vehicle-speed indicator, a superheterodyne receiver with a separate local oscillator has been used to detect the received signal and the small portion of the transmitted signal. Separation of the Doppler frequency shift has been carried out in subsequent intermediate and audio-frequency circuits.

The major part of the complexity of such systems has been removed in the equipment to be described. A single aerial is used and one klystron oscillator provides both transmitter and local-oscillator power. A three-stage audio amplifier follows the microwave crystal detector and a further four valves provide trigger circuits and a frequency-measuring circuit to complete the system.

2. Description of Equipment

The complete equipment, which is intended for installation in a motor car, is divided into three main parts:—

The aerial head, comprising the aerial, which at present is a paraboloid of 18-in. diameter, the waveguide circuit and the klystron oscillator. It is normally mounted on a short pillar attached to the rear of the operations car.

The electronics unit comprises amplifier and frequency-measuring circuits and, on a separate chassis, a vibrator power unit which is operated from a 12-volt battery. This complete unit is mounted in the boot, or other convenient position in the car.

A remote-control unit contains the speed-indicating meter and operating controls, and may be mounted inside or outside the car to suit the operational requirements.

It is proposed to describe the basic equipment and then to deal with various modifications and

* Now at Civil Aviation Administration, Air Department, N.Z.

MS accepted by the Editor, March 1955

† N.Z. Patent Application No. 109385

additions which have been incorporated as a result of experimental tests.

The waveguide circuit used is shown schematically in Fig. 1. The basis of the arrangement is the hybrid junction, and the 'rat race' form is illustrated. Two properties of the 'rat race' are used.

When transmitting, the klystron oscillator, operating in the 10,000-Mc/s region in the present model, supplies energy to arm 3 of the junction and this energy divides equally between arms 2 and 4. That going into arm 2 is absorbed in a matched load consisting of carbon-coated card.

The energy entering arm 4 is fed to the aerial, and radiated in a beam of approximately 5° total angular width between the half-power points. The total power radiated is of the order of 10 mW.

Although a theoretically perfect rat race has the property that arms, such as 1 and 3, are completely isolated, in practice there is a small leakage of power between them. The attenuation factor is in general greater than 30 dB; thus a small portion of the transmitted power leaks across to arm 1 in which is a standard microwave crystal detector. This leakage of power provides the local-oscillator power for mixing purposes.

A similar process occurs when reflected signals are received by the aerial. From arm 4 the energy divides equally between arms 3 and 1 with a negligible amount lost to arm 2. That going into the klystron arm is very small compared with the klystron power and its effect on the operation of the klystron can be ignored. The half of the received signal power entering arm 1 is mixed with the leakage power from the klystron and a process of homodyne detection occurs.

The resultant output from the crystal is the difference frequency between transmitted and received signals; i.e., the Doppler frequency shift due to movement of the target. For a radio-frequency in the 10,000-Mc/s region the resultant Doppler frequency shift for a target speed of 1 m.p.h. is about 30 c/s so that, for speeds up to 60 m.p.h., the circuits following the detector receive audio-frequency signals up to 1,800 c/s.

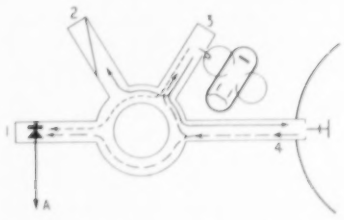

Fig. 1. *Hybrid waveguide junction connecting klystron transmitter, aerial and receiver.*

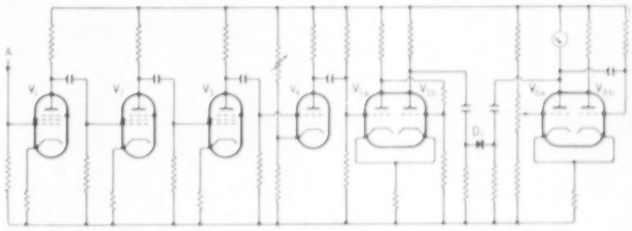

Fig. 2. *Circuit diagram of experimental receiver.*

The basic amplifier and frequency-measuring circuit is shown in Fig. 2. The first three stages, V_1, V_2 and V_3, constitute a high-gain audio amplifier designed for minimum hum pickup and microphony. It is important to ensure that the noise arising from all sources, including the vibrator power supply, which is contributed to the output of this amplifier is small compared with the noise arising from the crystal detector. Then the limiting sensitivity of the system is that set by the r.f. portion of the equipment. The remaining stages, V_4, V_5 and V_6 constitute the controlled trigger circuits and frequency-measuring circuit.

V_4 is a further amplifier acting as a squaring stage but with an adjustable bias control. This is provided by current flowing through the cathode resistor via a variable resistor to the h.t. line.

V_5 is a bistable multivibrator which produces a square wave with steep edges when operated by the somewhat variably-shaped waveform output from the previous stage. The object of this stage is to provide, by differentiation of its output and passage through a crystal diode D_1, a narrow negative-going pulse to trigger the final stage. This trigger pulse occurs for each cycle of the initial sinusoid input signal to the amplifier.

The final stage V_6 is a monostable multivibrator, producing a current pulse of constant amplitude and duration in the triode V_{6A}, which is normally cut off, each time the circuit is triggered. A meter in this anode circuit measures the mean current through the valve and can thus be calibrated to indicate frequency or speed.

It should be noted that the triggering sensitivity of the circuit is fixed by the bias condition of the squaring stage V_4. It is found, in fact, that a small signal, comparable or even somewhat less than the noise level, will 'capture' the trigger circuits and produce a steady meter reading of the correct value. However, to avoid an intermittent meter deflection in the absence of a moving target, the sensitivity was adjusted so that peaks of noise did not trigger the circuits. A modification to this condition will be dealt with later.

The vibrator power-supply unit, when operated from a 12-V battery, provides a positive supply of 300 volts which has a total ripple and hash content of less than 5 mV and also a negative supply of 180 volts which has a ripple and hash level of less than 1 mV. Both supplies are stabilized with standard regulator valves.

Heater supplies for the valves are obtained, through suitable filter circuits, from the battery.

3. Initial Tests

The equipment as described was used for experimental tests designed to prove the system as a whole and to determine the general sensitivity for different road vehicles. The overall performance will be discussed later, but these trials showed that although the basic performance was satisfactory certain modifications were desirable.

It was found advantageous to have some audible output of the Doppler frequency to assist the operator in aligning the aerial beam. Using headphones or a loudspeaker the aerial is readily aligned by adjusting its position to give maximum audio output from a vehicle travelling in the traffic lane being investigated.

A phenomenon occurred, disturbing to satisfactory operational use, in the form of intermittent 'flicks' of the meter indication under certain conditions. This was observed when a vehicle was first coming within range or just going out of range and, more seriously, in so far as operational use is concerned, when a vehicle well within range passed over a severe bump in the road surface. A typical example which could be examined at one test site was a railway crossing, when the meter reading dropped momentarily although it had been perfectly steady for several seconds previously.

There is a considerable variation in signal level returned from a road vehicle which, in general, is not important, as the signal stays well above the noise and trigger-sensitivity level and constant triggering and steady meter readings result. However, for a vehicle approaching from beyond maximum range, momentary increases in the signal level to above the triggering sensitivity level cause intermittent kicks of the meter. These disappear as the vehicle moves into range and a steady reading continues. The action as the vehicle moves out of range is similar.

In the case of a severe bump in the road the signal level can be reduced sufficiently to fall below the sensitivity level, which has been adjusted as indicated above, and triggering will cease for a short interval.

It was apparent that an increase in sensitivity would overcome this latter difficulty as the signal did not fall completely to zero. At such bumps in the road surface, with the triggering sensitivity increased, the signal could be followed audibly and the meter would continue to operate in the normal manner. However, with the sensitivity increased to this extent the noise level was sufficient to trigger the frequency-measuring circuit in the absence of a moving target.

To overcome these difficulties, some modification and additions were made to the circuit and, at the same time, a tuning-fork oscillator was added to provide a means of checking the calibration of the frequency-measuring circuits during operations.

4. Modifications

The final circuit incorporating the modifications is shown in Fig. 3. It will be seen that V_1, V_2, V_3 which constitute the audio amplifier, V_5 the bistable multivibrator and V_6 the frequency-measuring monostable multivibrator, are unchanged.

V_{4B} is a cathode follower driven in parallel with V_{4A} and provides the audible output of the Doppler frequency through a loudspeaker or headphones.

The circuit of valve V_{4A} has been changed to act as calibration oscillator or as a squaring amplifier. When the relay RL/1 is operated, this valve is connected with the drive and pick-up coils of the tuning fork to provide an oscillator of high frequency stability which is suitable to provide a frequency-measuring-circuit calibration check. The relay is operated by a switch in the remote control unit and the oscillation amplitude reaches a sufficient level within a few seconds to drive the subsequent circuits and operate the meter. The frequency generated by the fork corresponds to a certain meter reading—35 m.p.h. in this case—and by a remote control of the grid potential of V_{6A} the operator can make a correction to the frequency-circuit calibration if required. In practice, it has been found that after a few minutes' operation of the equipment, subsequent adjustments to the calibration are not necessary. In operation a calibration check takes between 5 and 10 seconds.

In the non-operated or normal position of the relay, V_{4A} still operates as an amplifier and squaring stage but its bias condition is now controlled by V_{7A} and V_{7B} which constitute an automatic sensitivity-control circuit having the property of increasing sensitivity as the signal level increases.

It operates in the following manner:—

The cathodes of V_{4A} and V_{7A} are connected to a common resistor, thus adjustment of the grid potential of V_{7A}, which is a cathode follower, controls the bias condition of V_{4A} by changing the potential of the cathode.

Consider the grid circuit of V_{7B}. Audio signals from the output of the amplifier valve V_3 are rectified by the crystal diode D_2 and the resulting waveform is smoothed by the resistance-capacitance circuit to provide a steady potential at the grid of the valve V_{7B}. This potential increases positively as the audio-signal level increases and vice versa. As a result of an increasing input signal, therefore, the anode potential of V_{7B} falls, which results in a fall in potential of V_{7A} grid circuit via the crystal diode D_3 and the resistance-capacitance combination in that circuit. It will be noted that a fall in potential is rapidly transferred to the grid V_{7A} as the capacitor is charged through the comparatively low forward resistance of the crystal diode. However, if the applied potential subsequently rises, the capacitor discharges through the high back resistance of the

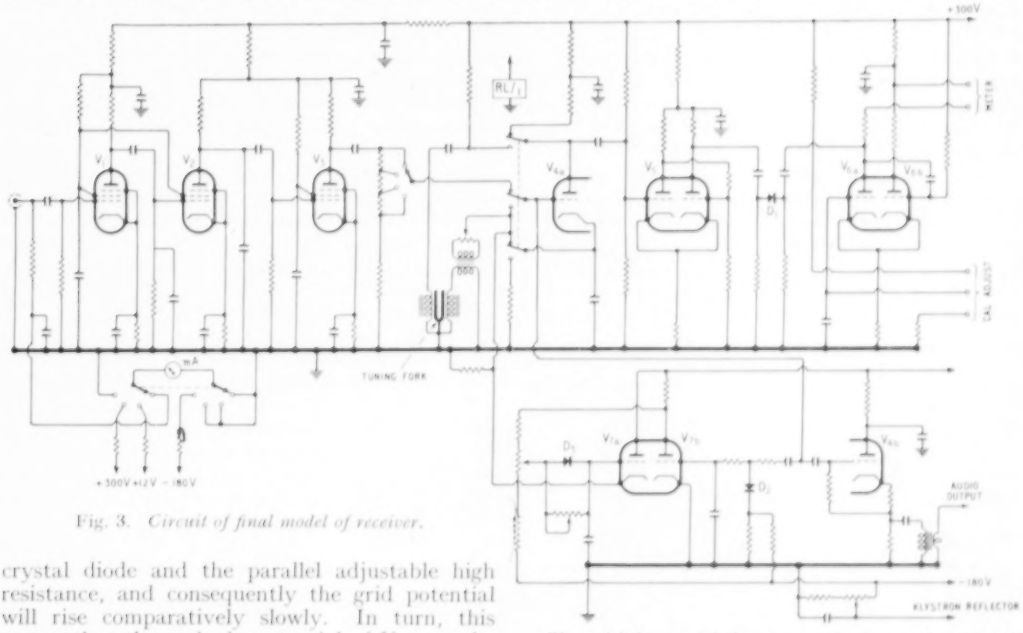

Fig. 3. *Circuit of final model of receiver.*

crystal diode and the parallel adjustable high resistance, and consequently the grid potential will rise comparatively slowly. In turn, this means that the cathode potential of V_{4A} can be reduced quickly but will increase slowly, as a result of variation of signal level from the audio-amplifier stages.

In effect, therefore, the circuit modification provides an automatic bias circuit operating so that the triggering sensitivity increases as the input signal increases, but falls only slowly if the input signal falls in level.

As a result the intermittent triggering at maximum ranges, and due to severe bumps at shorter ranges, is prevented in the following manner. Consider a vehicle approaching from beyond maximum range. Very small signals with instantaneous rises in level cannot operate the trigger circuits as the preset sensitivity is low. As the vehicle approaches, the signal level increases and the sensitivity increases due to the action of the automatic bias circuit. The sensitivity increase will follow the mean signal level rather than its fluctuation, due to the smoothing action of the component parts of the circuit. At a well-defined level of input signal the sensitivity will have so increased that the triggering action commences. The circuit has prevented early instantaneous triggering due to sudden signal peaks when the vehicle is beyond the normal maximum range. Sensitivity further increases and any subsequent fall in signal level occurs with the circuits at high sensitivity. Therefore once triggering has commenced it continues even if the signal level varies considerably.

Since high sensitivity can only be realized with an input signal present it is possible to operate this circuit at a considerably higher ultimate sensitivity than the original circuit. In the original circuit operation by noise peaks in the absence of a signal had to be avoided, but since the trigger circuits will 'capture' the signal in the presence of noise the modification allows the ultimate sensitivity to be much higher than that of the original circuit. This means that since the sensitivity can fall only slowly, short-term low-level signals continue to give steady meter readings if the sensitivity has previously been raised by high-level signals. Thus the variations of signal

at severe bumps (i.e., railway crossings) do not cause interruption to the triggering action.

The other addition to the circuit is a switched meter to check the various supply voltages and the rectified current from the crystal detector. This current is adjusted to a maximum for the optimum setting of the klystron reflector voltage and, because the voltage supplies are stabilized, *no* further attention is required during an operation. It has been found in practice that in general no further adjustment is required over a period of several operations.

5. Experimental Model of Equipment

In the experimental equipment the aerial head has a domed Perspex front cover, and a cylindrical metal cover behind the aerial protects the klystron and the associated waveguide components. The unit when assembled is weatherproof and is so constructed that when mounted on a short pillar at the rear of a car it can be carried over rough roads and up to speeds of 70 m.p.h. without damage. The assembled electronic units are on shock-absorbing mounts and installed in the boot of the car.

The remote-control unit contains the essential operating controls, a headphone jack and the indicating meter. In future models, apart from a mechanical redesign of the electronic-circuit units, the fixed meter will be replaced in the control unit by a loudspeaker, and portable meters will be jacked into this unit on extended leads.

The trial installation in an operations car is shown in Fig. 4. It will be seen that with the car

Fig. 4. *Experimental installation in car.*

placed at an angle to the highway, the aerial head can be aligned to cover vehicles approaching from either direction.

In the illustration the remote-control unit is placed on the dashboard of the car but, as circumstances require, it could be placed inside or outside to suit the operator.

6. Experimental and Operational Trials

Following the modifications to the equipment, an extended series of tests and trials have been carried out, both in laboratory vehicles and as a trial installation in a Transport Department car. The results are summarized below and some of the technical problems affecting operational use are discussed on the basis of the information gained. A number of further operational facilities are also briefly considered.

In general, the tests of the equipment have shown the system employed to be completely satisfactory, the ranges on all types of vehicles are more than adequate and the advantages in weight, power consumption, ease of operation and maintenance to be expected from the simplicity of the arrangement have been realized.

Using an 18-in. diameter paraboloid aerial ranges on medium-sized cars were in excess of 300 yards, on lorries, trucks, buses and similar large vehicles 600–800 yards was normally obtained on a straight road. The ranges varied more with the body shape of cars than with size, the modern streamlined version producing a signal noticeably smaller than the older types of bodywork. However, the smallest modern car produced steady meter readings to ranges in excess of two hundred yards which corresponds to a time greater than 7 seconds for a speed of 60 m.p.h. A man could be observed walking at about one hundred yards and small birds passing through the aerial beam at ranges up to about 50 yards produced audible notes and distinct meter deflections.

A suitable height for the aerial is between 4 ft and 6 ft. There is some reduction in range with the aerial placed at heights much below 4 ft but, even so, ranges in excess of 100 yards were obtained on medium-sized cars with the aerial placed on the road surface. No evidence has been obtained of an interference pattern in the vertical polar diagram due to reflections from any type of road surface.

Difficulty arises when a number of vehicles are observed simultaneously, and in general it is desirable to limit the coverage in an attempt to observe one vehicle at a time. The equipment indicates the speed of the target producing the largest signal and laboratory checks show that interference between signals occurs when the smaller is greater than about 0·7 of the larger, measured as a voltage at the amplifier input. A confused meter reading occurs when two or more vehicles produce signals of comparable

level. This can occur, for example, with a small car at a short range and a bus at much greater range.

Various palliatives can be applied to the problem of isolating single vehicles. The parameters of the system which affect the coverage are the receiver sensitivity and aerial beam-width. The aerial beam-width can be varied by change of aerial size or wavelength used; the general discussion is unaffected.

It may appear at first sight that a reduction in beam-width by increasing the aerial diameter would immediately solve the difficulty of reducing the horizontal coverage. However, if, for example, the 18-in. paraboloid is changed to a 36-in. paraboloid the beam-width is halved, but the maximum range is doubled. Consequently, the maximum width of the horizontal coverage is unchanged. The same maximum width of coverage is obtained by halving the size of the aerial as illustrated in Fig. 5(a). It is apparent that, if the aerial size is changed in this way, the sensitivity of the system must be adjusted to maintain the same maximum range if the benefits of change of horizontal beam-width are to be fully realized. Fig. 5(b) shows the effect of the 36-in., 18-in. and 9-in. paraboloids with the sensitivity adjusted for 200 yards maximum range in each case.

Since it has been found in practice that a vertical beam-width of about 5° is satisfactory for general use, it is desirable that the vertical dimension should be maintained and the horizontal aperture varied for changes in horizontal cover. Maintaining full receiver sensitivity and varying only the horizontal beam-width, the coverage obtained for a horizontal aperture of 36 in., 18 in. and 9 in. for a target on which the maximum range for an 18-in. × 18-in. aerial is 200 yards is shown in Fig. 5(c). A road width of 30 ft is indicated and an ideal site on a slight bend is used.

For a more usual site at the edge of a straight road the coverage obtained is less complete but still adequate as Fig. 5(d) indicates.

It can be seen that for different traffic conditions somewhat different alignments of the beams and beam-widths are desirable, L_1, L_2 and M_1, M_2 in (c) and (d). The mid-size aerial gives suitable cover for a low traffic density on the 30-ft road; traffic in both lanes can be followed. For observation of a single lane it is aligned as indicated along the edge of the road. The narrower beam of the 36-in. aperture is clearly more useful for single-lane traffic observation but for broad coverage of a roadway much in excess of 30 ft, it is inadequate and may require a certain amount of following of vehicle to be carried out. The broad beam of the 9-in. aperture is suitable for general coverage of a wider road, although the maximum range obtained is reduced.

In addition to the variation of aerial size and alignment a further modification of coverage is possible by reducing the receiver sensitivity. The general effect is a shrinking of cover for a particular aerial with results which can be visualized for the various diagrams.

As an indication of practical results it has been found that, operating on a wavelength of 3 cm, the 18-in. paraboloid, which produces a horizontal and vertical angular beam-width of about 5°, gives a reasonable compromise, for New Zealand traffic conditions, between general cover and the possibility, by alignment along the road edge, of coverage of a single traffic lane.

It should be noted that the coverage patterns are for a vehicle of a given size; for a smaller vehicle they will be reduced, and enlarged for a larger vehicle. Thus, if interference by a second vehicle is to be considered, the appropriate cover diagram for its size and hence maximum range must be used.

It is apparent that reducing the maximum range by operation within several hundred yards

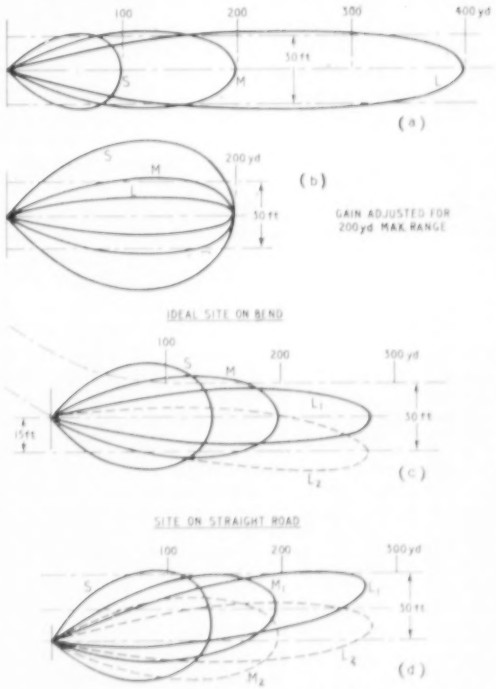

Fig. 5. Variation of beam-width and coverage for various aerial sizes. In (a) and (b) S, M and L are for mirrors of 9-in., 18-in., and 36-in. diameter respectively; in (c) and (d) these letters represent mirrors of 9 in. × 18 in., 18 in. × 18 in. and 36 in. × 18 in.

of a road bend will reduce the number of vehicles within the coverage. Vehicles beyond the corner rapidly pass out of the aerial beam and cannot cause confusion with vehicles within cover.

7. Subsidiary Tests

Further details of operational techniques are more appropriate to discussion elsewhere but some indication of various subsidiary tests are of interest.

Interference by slow-moving traffic which could screen faster-moving vehicles (e.g., bicycles and motor cars) can be removed by the use of a high-pass audio filter. A filter designed to pass frequencies above approximately 900 c/s was placed in the input circuit to the audio amplifier. This removed indications of vehicles travelling at less than 30 m.p.h. but speeds above this were displayed normally. This technique could be developed to cover speed ranges required operationally.

Various types of frequency-measuring systems have been considered as alternatives to that described. Vibrating-reed indicators have the property of displaying a number of frequencies and thus the speed of several vehicles simultaneously. Similarly, a bank of filters operating indicators would provide the same facility. Modifications to the circuits would be considerable and, in particular, a large dynamic range would be required in the amplifier stages to avoid saturation effects by which a large signal could obliterate a smaller one.

In other applications of the system, where post-detector integration is desirable to exploit the maximum sensitivity possible with the homodyne detector, the complication of filter circuits may well be justified. To maintain the simplicity of the equipment as a vehicle speed indicator they have not been pursued further to date.

It is apparent that recording of vehicle speeds can be accomplished by replacing the visual meter by a recording meter of the type in which a pen writes on a moving-paper strip. This has not been requested as an operational aid for New Zealand use, although the need for the method or a similar one has been foreseen.

A number of tests have been made with a commercial magnetic tape recorder as a means of making a permanent record of a vehicle speed. The audio output from the equipment was fed into the recorder and the operator could, by means of a switch and a microphone, make a verbal statement of the characteristics of the vehicle being recorded. At a later time, in the laboratory, the recording was played back through a loudspeaker and into a counting circuit and meter as used in the equipment. The levels of speech and Doppler frequency were so arranged that only the latter operated the meter. The result was a meter indication of speed, a verbal description of the vehicle, the time, etc., and then a return to the meter indication until the vehicle moved out of range. To remove inaccuracies due to speed variations of the recorder it is suggested that double track recording should be employed, the second track being used to record a constant frequency generated at the site, e.g., a tuning-fork oscillator as used at present for calibration checks.

It has been found that an operator very quickly learns to interpret the approximate speed of a vehicle from the audible Doppler frequency. The loudspeaker provides a very suitable warning to him of the approach of a vehicle and the pitch of the note emitted indicates whether or not he is required to take any further action. Some checks were carried out to determine if, in fact, an observer could rapidly compare the Doppler frequency with a standard frequency such as that provided by the tuning fork. With untrained and unskilled personnel it was found that, given the facility of a switch to alternate the tones heard, frequencies above 1,050 c/s and below 950 c/s could be distinguished immediately from a standard frequency of 1,000 c/s. At present the use of the audible Doppler frequency is considered a convenient warning technique only, apart from the assistance it gives in aerial alignment.

8. Accuracy

A detailed discussion of the possible errors which can arise throughout the equipment is given in the Appendix. In this estimation the various errors have been added to show the maximum error which could occur under the most pessimistic conditions.

The resulting figure is a maximum possible error of

$(v/36 + 1)$ m.p.h.

for a true speed of v m.p.h.

It should be emphasized that in practice the error will always be less than this figure and, if circumstances are at all favourable, considerably less. Practical checks of accuracy against vehicles fitted with calibrated speedometers have not produced differences of measured speed greater than 1 m.p.h. and a significant part of this difference could well be associated with observation of the speedometer and the speedometer error itself.

9. Conclusion

The equipment described and discussed in this paper has proved, as a result of experimental tests and quasi-operational trials, that the new form of radio-frequency circuit and the associated electronic circuits employed are satisfactory. The sensitivity is more than adequate for use as a

vehicle-speed indicator, and the expectation that the overall simplicity would give obvious advantages in size, weight, operating and maintenance problems has been confirmed. The experimental equipment has been transported by air to Australia and the United Kingdom for demonstration by personnel unfamiliar with it. The demonstrations have been successful and so far as is known no maintenance has been required. A number of models are being manufactured in a suitably engineered form for the New Zealand Transport Department and authorities in other countries have expressed interest in the development. It is considered that further development and trials using a higher radio frequency, possibly 24,000 Mc/s, would be worth while, particularly since the aerial size could be appreciably reduced.

Acknowledgments

The author wishes to acknowledge the assistance of his colleagues at the Dominion Physical Laboratory, in particular, Mr. E. S. Gilfillan, who carried out much of the initial experimental work, and Mr. W. A. Penton who provided invaluable assistance throughout and who was responsible for the development of the tuning-fork oscillator.

In addition, the co-operation of the New Zealand Transport Department and the members of that Department who assisted in trials is gratefully acknowledged.

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APPENDIX

(Overall Error in Speed Indication)

Total Error

It is proposed to consider the various errors which can arise throughout the equipment, and it is emphasized that the overall error in practice will always be less than the figure derived here by summation of the individual errors. This process of summation produces a figure which is satisfactory from a legal aspect when the equipment is used for enforcement purposes.

The overall stability and accuracy of the method of determining the speed of a road vehicle, using this equipment, depends upon a number of factors.

(1) Radio-frequency measurement and stability
(2) Calibration-oscillator stability
(3) Frequency-measuring circuit stability
(4) Accuracy of meter indication and reading of meter

Klystron Stability

From the basic equation

$$\text{Doppler frequency} = \frac{2vf}{c}$$

it is apparent that a change in f will produce a corresponding change in the Doppler frequency.

Using a standard commercial wavemeter, the klystron could readily be set to 3 parts in 10,000, giving a possible initial error of 0·03%.

Variation of klystron frequency must now be considered; it depends on the change of resonator-volume and the voltage applied to the reflector. For the 723 A/B klystron the following characteristics are given:—

(a) Temperature Coefficient: between (0 and −0·20 Mc/s)/°C at 9,000 Mc/s.

Allowing a temperature change of 20°C after the initial warm-up period—a pessimistic estimate—the resultant error would be 0·04%.

(b) Reflector Voltage—this is stabilized by gas-discharge regulator valves which can have a short-period variation of a few millivolts and a long-term variation of about 0·2 volt.

As a result, the frequency change due to voltage variation of the reflector, normally about (2 Mc/s)/volt, can be neglected as the resultant error should not exceed 0·004%.

The total error which could be attributed to the klystron is therefore 0·03% + 0·04%; i.e., 0·07%.

Calibration Oscillator Stability

It has been found experimentally that the simple valve-maintained tuning fork used has a temperature coefficient of the order of 1 part in 10,000 per °C. Allowing a temperature change of 20°C after initial calibration the error introduced would be 0·2%.

Frequency-Measuring Circuit

Investigations of the circuit show it to have several possible errors:—

(a) variation of current with h.t. voltage = 0·4% per volt

(b) variation of current with heater voltage = 1·7% per volt

(c) a departure from a linear relationship of current against frequency

Since the h.t. voltage is stabilized and the heater supply is direct from a battery, the errors arising from variations in these voltages can be neglected, particularly as calibration checks are carried out at intervals of a few minutes. It has been found, however, that the departure of a current value for a particular frequency injected into the circuit may vary by an amount up to 0·4% from the value determined by mean linear relationship of current against frequency. This figure is of significance since, if it occurs at the calibration point, it introduces an equivalent error of up to 0·4% throughout the range. If at some other point there is also an error of 0·4% the overall error may be the sum of both, giving a possible maximum of 0·8%.

The transfer of the error at the calibration point throughout the range will also occur for errors in calibration frequency, meter error, and meter reading error.

Meter

High-quality laboratory instruments are not suitable for an operational equipment of this type but a commercial meter of robust construction capable of retaining an accuracy of 0·5 m.p.h. over a calibrated range up to 60 m.p.h. maximum is used.

The direct meter error is thus 0·5 m.p.h. As indicated, this introduces a further possible error throughout the range of 0·5/35 or 1·4%, calibration being carried out at a frequency corresponding to a speed of 35 m.p.h.; thus the total error due to the meter is 1·4% + 0·5 m.p.h., or

$$\frac{v}{70} + 0{\cdot}5 \text{ m.p.h. at } v \text{ m.p.h.}$$

Observation Error

It is proposed to allow the operator a maximum reading error of 0·5 m.p.h. during operations; with a large-scale meter this is a liberal allowance.

For calibration purposes he is required to adjust the needle to a specific mark and an accuracy of 0·1 m.p.h. can be expected. This results in a possible error of $\frac{0{\cdot}1}{35} \times 100 = 0{\cdot}3\%$ throughout the range.

Overall Accuracy

From the discussion it is apparent that the accuracy of a speed determination depends upon the speed and further that the errors associated with the meter are greater than those due to all other causes.

The possible maximum errors due to klystron, calibration oscillator and frequency-measuring circuit total 1·07%, and those due to the meter 1·7% + 1 m.p.h., giving a total maximum error at v m.p.h. of $\left(\frac{v}{36}+1\right)$ m.p.h.

It should be emphasized that this is the maximum error obtained by adding individual errors, and the error in practice should always be considerably less.

Error due to Non-Radial Motion of Target

Since the equipment will, in general, not be sited directly in line with the direction of motion of the target it will measure the component of the velocity radial to the equipment. If the site is 10 ft from the line of motion the target velocity will not exceed the measured velocity by more than 1% until the target is within 70 ft, and for a 2% error, within a range of 59 ft.

For a siting error of 20 ft, such as may apply to vehicles on the far side of a road, the minimum ranges for the error not to exceed 1% is 140 ft, and 2% it is 118 ft; the errors are always such that the measured speed is less than the true speed.

CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Electrostatic Loudspeakers

SIR,—Your Editorial of May 1955, on this subject, has just come to my attention by being quoted and amplified in the issue of *Wireless World* dated February 1956, page 54. This is my excuse for referring to your Editorial so long after its publication.

When a symmetrical electrostatic loudspeaker is fed from a push-pull amplifier there is no necessity for any signal current to flow in the connection of the diaphragm to the supply of polarizing voltage. This connection can therefore have a high resistance. The resistance can indeed be made so high that the electrostatic charge on the moving diaphragm has no chance of varying during the audio-frequency cycle in spite of large diaphragm excursions and consequent changes of capacitance. Several advantages accrue, such as greater freedom of choice of diaphragm material, but pride of place must be given to the virtual elimination of the non-linear distortion which was a serious fault of earlier designs. All this you freely acknowledge in your Editorial, but apparently you are still not satisfied and you are looking for something even better. (This idea is amplified and made more explicit in the *Wireless World* article.)

You calculate that, even under constant-charge conditions, a force is developed on the diaphragm when it moves away from its mid position and you promptly assume, without any explanation, that this force must be objectionable and should be eliminated if possible. But why? Your calculation shows that the force is strictly proportional to displacement, so that it will not introduce non-linear distortion. The sign of the force corresponds to negative stiffness; perhaps you are anxious about stability? But at zero frequency the negative stiffness effect is equally present and further aggravated by non-linearity (the series resistance being ineffective at zero frequency). The positive mechanical stiffness which it is necessary to give the diaphragm (by suitable tensioning) to ensure stability at zero frequency will be more than adequate to ensure stability under dynamic conditions. The negative electrical stiffness merely reduces the total effective stiffness of the diaphragm system. The effect is small, but entirely beneficial.

It is interesting to speculate on what will happen if (in spite of the above argument) you are still determined to avoid the effect. You have proposed the use of a diaphragm material having high volume resistivity and this could certainly be provided. This would prevent migration of charges from one surface to the other. However, a dielectric is 'transparent' to electrostatic fields so that the charge, irrespective of its distribution between the two surfaces, is equally 'visible' from both signal electrodes so that your object is defeated. You might attribute this failure to the fact that, although you have provided good d.c. insulation, the two surfaces are still connected together for a.c. by the large capacitance existing between the surfaces separated by a thin dielectric. You might then try a very thick diaphragm (thick compared with the working air gaps) or, with great ingenuity, two diaphragms connected mechanically to take the electrostatic pull but sufficiently separated to reduce the capacitance to a negligible value. If you succeeded in this, your loudspeaker would then fail for another reason—you would find that you had open-circuited the only path through which the amplifier could send its signal.

The situation may be summarized briefly thus: Providence has decreed that the diaphragm be endowed with a small measure of negative stiffness; you may disdain the gift, but you can refuse it only by the drastic expedient of keeping your loudspeaker permanently disconnected.

T. C. NUTTALL

Cinema-Television Ltd.,
London, S.E.26.
30th January 1956.

NATIONAL PHYSICAL LABORATORY

Professor G. B. B. M. Sutherland, Sc.D., F.R.S., Professor of Physics and Director of the Biophysics Research Centre in the University of Michigan, has been appointed Director of the National Physical Laboratory in succession to Sir Edward C. Bullard, Sc.D., F.R.S. Until Professor Sutherland takes up his appointment, R. L. Smith-Rose, C.B.E., D.Sc., M.I.E.E., Director of Radio Research in the Department of Scientific and Industrial Research, has been appointed Acting Director. Prior to his appointment at the University of Michigan, Professor Sutherland was Reader in Spectroscopy at Cambridge.

D.S.I.R.

Professor H. W. Melville, F.R.S., has been appointed Secretary to the Committee of the Privy Council for Scientific and Industrial Research in succession to Sir Ben Lockspeiser, K.C.B., F.R.S., who is retiring.

INSTITUTE OF RADIO ENGINEERS

L. C. Jesty, B.Sc., M.I.E.E., Chief of the Television Research Group, Marconi Research Laboratories, has been elected a Fellow of the Institute of Radio Engineers "for leadership and personal contributions in the development and evaluation of television systems".

NEW BOOKS

Transistor Electronics

By Arthur W. Lo, Richard O. Endres, Jakob Zawels, Fred D. Waldhauer and Chung-Chih Cheng. Pp. 521 + xii. Prentice-Hall, Inc., U.S.A. British Agents:—Bailey Bros. & Swinfen Ltd., 46 St. Giles High Street, London, W.C.2. Price 96s.

The initial chapters cover physical concepts, equivalent circuits, the basic forms of amplifier circuit and bias circuits. Two chapters are then devoted to low-frequency and power amplifiers.

In Chapter 7, the additional concepts required for high-frequency operation are introduced and, in Chapter 8, there is a return to the physical aspects of the transistor. The remaining four chapters deal with high-frequency amplifiers, oscillators, modulation and demodulation and pulse circuits.

Except in Chapter 8, on the interpretation of transistor parameters, the mathematical level does not often go beyond the ordinary algebra of circuit analysis although, in a few places, equations are expressed in matrix form.

The book deals, in the main, with the junction transistor and the authors have invented a new graphical symbol for it, so that it may be readily distinguished from the point-contact transistor. It is very similar in its general effect to the ordinary valve symbol.

The treatment generally is based upon equivalent circuits for the transistor. There are the usual ones for low frequencies, but at high frequencies other, much more complex, types make their appearance.

The book gives a good general treatment of the transistor and can be recommended to those who want more than an elementary discussion but yet do not wish to venture into the higher mathematics.

W.T.C.

Impulstechnik

A series of lectures edited by Dr. F. Winckel. Pp. 346 + viii with 242 illustrations. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price D.M. 37.50.

This is a series of lectures arranged by the extramural department of what is now called the Technical University of Berlin-Charlottenburg, in conjunction with the Berlin Elektrotechnischen Verein.

In all transmission systems there is an increasing use of pulse modulation in place of amplitude modulation. In these lectures the various problems that arise in the production and use of pulse modulation are explained and discussed by a number of experts who have specialized in the various fields.

The first lecture by Dr. Fischer of Darmstadt deals very fully with the mathematical analysis of pulses and their modulation. The second lecture by Dr. Meyer-Eppler of Bonn University discusses the application of information theory to pulse problems, while the third by Prof. Kroebel of Kiel explains the use of pulse technique in measurements in physics. The fourth lecture is by Dr. Holzwarth of Siemens and Halske, Munich, and deals with frequency bandwidth, noise and interference. The fifth lecture is by W. Bruch of the Telefunken Co. and discusses the application of pulse technique to television, while the sixth, by Dr. Kramar of the Lorenz Co., Stuttgart, explains its application to radio navigation. The seventh lecture by Dr. W. Dieminger is on the application of pulse technique to exploration of the ionosphere, and the eighth by Dr. Speiser of the Zurich Institute for Applied Mathematics is on impulse problems in electronic calculating machines. The ninth lecture by Dr. Hermann of the A.E.G., Berlin, deals with pulse technique in optics, the tenth by Dr. H. Fack with the transmission of pulses in the nervous system. The final chapter, also by Dr. Fack, is outside the series of lectures on which the book is based and is added as a complementary appendix to his lecture on the nervous system. It deals with the application of information theory to the nervous system, with special reference to hearing and, as an indication of the thoroughness of the treatment, we may mention that thirty-five pages are devoted to the information capacity of the ear.

Most chapters conclude with a large number of references to the literature of the subject, the total for the eleven chapters being 347. The book is very well produced and illustrated; it is undoubtedly a valuable addition to the literature of the subject.

G.W.O.H.

Die Laplace-Transformation und ihre Anwendung in der Regelungstechnik

Compiled by R. Herschel. Pp. 142 with 71 illustrations. Verlag R. Oldenbourg, Rosenheimer Strasse 145, Munich, Germany. Price D.M. 12.80.

In April 1954, the Society for Applied Mathematics and Mechanics in Munich established a committee to deal specially with the mathematics of control circuits and systems. This committee held their first public meetings in Essen in October 1954, when three days were devoted to the reading and discussion of eleven papers on the application of the Laplace transformation to the calculation of control systems. A general knowledge of the fundamental theory of such systems and of their practical applications was assumed, the main object of the lectures being to show the important part that the Laplace transformation can play in the subject.

The eleven papers which are contained in this volume, have been revised by the authors and modified and extended to take into account points raised in the discussion. R. Herschel, who gave one of the lectures, has acted as editor, and has made the eleven papers, so far as possible, into one organic whole. Some overlapping is an advantage, as the reader will be shown things from several different points of view.

The authors of the eleven papers are as follows:—Dr. W. Oppelt, Frankfurt; Prof. G. Doetsch, Freiburg; R. Herschel, Constance; Dr. St. Schottlaender, Würzburg; Dr. J. Dörr, Darmstadt; Prof. A. Leonhard, Stuttgart; Prof. O. Schäfer, Frankfurt; Prof. K. Küpfmüller, Darmstadt; Dr. R. C. Oldenbourg, Munich; Prof. H. F. Schwenkhagen, Wuppertal; J. Peters, Hamburg. The first paper lays foundations by developing the formulae of the feedback or servo system; the second paper, which occupies about a quarter of the book, is devoted to a very complete description of the Laplace transformation. In the following eight papers the Laplace transformation is applied in various ways to various problems that arise in connection with control systems. The final paper deals with the application to control systems of the methods employed in communication systems, the Laplace transformation being regarded as a sort of common denominator.

The book has evidently been carefully prepared and as the joint effort of eleven scientists it can be unreservedly recommended to anyone with the necessary knowledge of German.

G.W.O.H.

Electronic Transformers and Circuits (2nd Edition)

By Reuben Lee. Pp. 360 + xvi. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 60s.

This book is mainly concerned with the operating principles and design of small power transformers and is

noteworthy for the large number of design charts included. The value of some of these is limited slightly to the British user because of the adoption, natural enough in an American book, of American wire gauges.

The theory is very elementary, but probably adequate, since most users of the book will doubtless rely mainly on the charts for design purposes. Rectification, and its effect on the transformer, is dealt with on the basis of Schade's work and, again, largely by means of graphs.

It is a good feature of the book that the treatment is not restricted to 60 c/s. "High-frequency" supplies of up to a few kc/s are covered. Audio-frequency transformers are dealt with, though much less thoroughly, and there is a chapter on pulse transformers in which line-scan transformers are mentioned.

Ferrites and dust-iron are considered rather superficially and in one chapter things like i.f. transformers and r.f. tuning coils are discussed. These seem out of place, for the treatment is quite inadequate and they are, in any case, but little related to the main theme of the book.

W. T. C.

I.E.E. Awards

The 34th award of the Faraday Medal has been made by the Institution of Electrical Engineers to Professor G. W. O. Howe, D.Sc., LL.D, M.I.E.E., for "his pioneering work in the study and analysis of high frequency oscillations and on the theory of radio propagation; and for his outstanding contributions to engineering education".

Professor G. W. O. Howe, D.Sc., LL.D.

From 1921 until his retirement in 1946, Professor Howe was the James Watt Professor of Electrical Engineering in Glasgow University. For nearly 30 years he has been Technical Editor of *Wireless Engineer*.

The Institution of Electrical Engineers has elected to Honorary Membership, Colonel Sir Arthur Stanley Angwin, K.B.E., D.S.O., M.C., T.D., D.Sc.(Eng.), "in recognition of his outstanding life's work in the field of telecommunication".

OBITUARY

Dr. Eric C. S. Megaw, director of physical research at the Admiralty since 1951, died on 25th January at the age of 48. He was for 16 years in the G.E.C. Research Laboratories and left in 1946 to join the Admiralty Signal and Radar Establishment where he became superintendent of research. He received the Duddell Premium of the I.E.E. for his work on methods of generating super-high frequencies.

Norman Charles Robertson, C.M.G., M.B.E., died on 1st April at the age of 47. He had been with E. K. Cole, Ltd., since 1930 except for two years' voluntary service with the Ministry of Supply when, in 1951, he became director-general of electronics production. He was appointed to the Board of Directors of E. K. Cole, Ltd., in 1943 and became deputy managing director in 1945.

MECHANICAL HANDLING EXHIBITION

This exhibition, which is organized by *Mechanical Handling*, is being held at Earls Court from 9th to 19th May. There will be more than 250 exhibitors and associated with the exhibition will be the first international Convention with papers from Britain, Ceylon, Switzerland, U.S.A., Canada, Australia and Germany.

Tickets for the various sessions of the Convention and also tickets of admission to the exhibition are obtainable from Mechanical Handling Exhibition, Dorset House, Stamford Street, London, S.E.1. The exhibition is open to the public, admission 2s. 6d., from 10 a.m. to 6 p.m.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for January 1956

Date 1956 January	Frequency deviation from nominal: parts in 10^8	
	MSF 60 kc/s 1429-1530 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.
1	−0·1	−1
2	−0·1	−1
3	−0·2	−1
4	−0·2	0
5	−0·2	0
6	−0·2	−1
7	−0·1	0
8	−0·1	+1
9	−0·1	+1
10	−0·1	0
11	−0·4	0
12	−0·4	0
13	−0·4	+1
14	N.M.	+2
15	N.M.	N.M.
16	−0·3	0
17	−0·3	+1
18	−0·3	+1
19	−0·3	+1
20	−0·3	+1
21	−0·3	+1
22	−0·3	+2
23	−0·3	+2
24	−0·2	+2
25	−0·3	+2
26	−0·2	+2
27	−0·3	+1
28	−0·3	+3
29	−0·3	+1
30	−0·2	+1
31	−0·2	+1

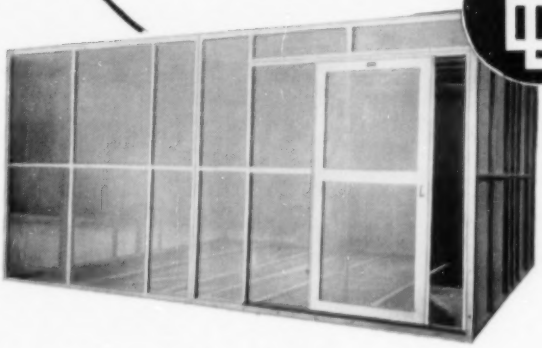
The values are based on astronomical data available on 1st February 1956.

N.M. = Not Measured.

SCREENED ROOMS

(FARADAY CAGES)

Two typical screened compartments designed to customers' special requirements. Designs and prices submitted on request.



A screened compartment may be used in two ways: as a barrier surrounding a source of radio frequency energy (as from electro-medical or R.F. heating processes) to prevent interference with radio, or to exclude R.F. energy, e.g. as a "quiet room" for the alignment and test of sensitive electronic apparatus.

To achieve the necessary high values of attenuation demands great care in design and manufacture. The door design is most important: it must be so made that optimum bonding over the perimeter is achieved when the door is closed, whilst being easy to operate, and without complex bolting mechanism. Our special multi-contact sliding door meets all these requirements.

In general, our screened rooms are covered in galvanised expanded steel, this being mechanically strong and corrosion-resistant. Performance, especially in the frequency range of 50-500 Mc/s, can be greatly improved by the use of a double screen, the two layers being spaced some 4 inches.

It would be possible to improve performance by covering the walls in solid metal sheet, but this has so many disadvantages, such as ventilation problems, and the possibility of inducing claustrophobia, that the advantages gained are generally not worth while. There is considerable advantage in the occupants being able to see out and to be seen.

Our rooms are prefabricated to permit easy assembly on any site, and subsequent dismantling and re-erection without loss of efficiency. We will design special compartments, but in general our standard construction of a wooden frame covered in a fine galvanised expanded steel (sections being easily transportable, and assembled with clamping bolts) is the most satisfactory.

It is usually necessary to bring various services into a screened compartment. In the case of compressed air, gas, etc., no interference will be introduced, provided all pipes are brought in at the same position as the main earth bond and connected securely to the screens. With power supplies, special filters are required to prevent interference coupling. We can quote for filters, covering the complete range from 10 kc/s upwards. It should be remembered that the filter is still the weakest link in the chain.

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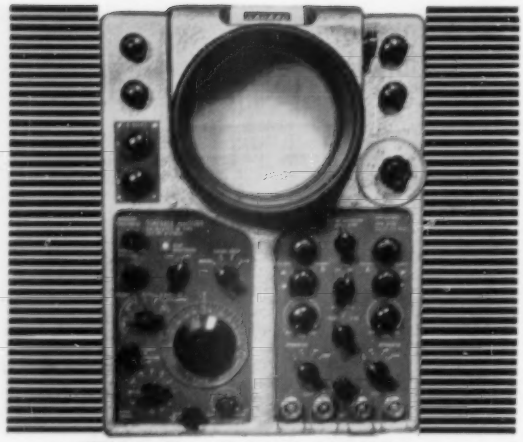

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By E. M. SQUIRE. The new fourth edition of this popular book has been brought up to date with modern developments. It presents a clear summary of the general practical theory of the most important and commonly used circuits in modern radio receivers. A straightforward explanation for members of the radio industry and radio students.
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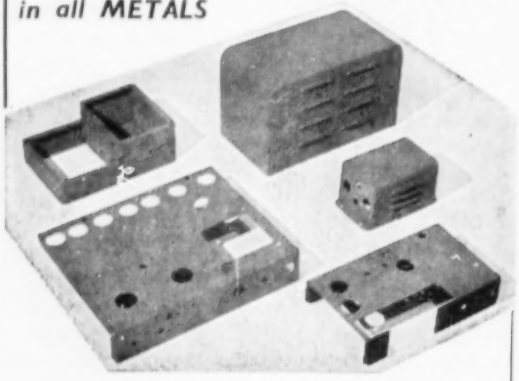

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We specialize in the design and manufacture of electrical filter units for the communications industry. All types of lowpass, highpass and bandpass filters are obtainable, including precision types with tolerances better than $\frac{1}{2}$ dB.

We also manufacture light and heavy duty types of suppression filters for the protection of screened cages or whole buildings or for the suppression of electrical machinery.

Standard types for through currents from 1-100 amperes cover frequencies from 150 Kc/s to 300 M/cs, special types are also available with the frequency range extended down to 1 Kc/s for the protection of electric computers and similar equipment.

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APPOINTMENTS—The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order, 1952.

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STAND OFF INSULATOR

For 1,500 volt working
Overall height 1·1″
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Standard maximum capacities up to 13pF. Voltage 500 D.C. Base $\frac{3}{8}$″ square with fixing centres for 10BA $\frac{1}{4}$″ apart

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The Edison Swan Electric Co. Ltd., Cosmos Works, Brimsdown, Enfield, Middlesex, has vacancies in its Research and Development Departments for:—

1. Development Engineers for work on design and development of thermionic valves.
2. Technical Assistants for work in connection with design and development of thermionic valves.
3. Mechanical Engineers interested in the problems of mass production associated with thermionic valves.

These vacancies are the result of a rapid expansion in the Company's activities. The positions are progressive and carry the advantages of a Pension Scheme.

Applicants for vacancies (1) should have an Engineering or Physics degree, but applications from candidates with H.N.C. or equivalent will be considered.

Applicants for vacancies (2) and (3) should have Ordinary N.C. or H.N.C. or Inter B.Sc. or equivalent.

The starting salary will be in accordance with the qualifications, experience and age of the applicants.

Applications should be in writing and will be treated with the strictest confidence.

Apply to **Mr. J. Donegan, Chief Engineer, Valves.**

HER MAJESTY'S OVERSEA CIVIL SERVICE

Vacancies exist for

Executive Engineers in the East Africa Posts and Telecommunications Administration

Duties include preparation of underground cable schemes for local subscribers distribution, trunk and junction cables, loaded and unloaded; preparation of cost comparisons and of development studies; and control of subordinate staff.

Appointment is pensionable in the salary scale £852-£1,620 per annum plus a temporary cost of living allowance of 10 per cent salary. Government quarters are provided, if available, at a rental of between £30 and £60. Free passages are provided for the officer, his wife, and up to two dependent children. Leave is granted at the rate of five days for each completed month of residential service.

Candidates should be between 26 and 40 years of age and must have passed or be exempt from Sections A and B of the examination for A.M.I.E.E. and have wide experience of all aspects of planning and implementation of local distribution and junction cable schemes. A knowledge of cables for operation up to 140 kc/s would be of advantage with special reference to loaded and unloaded lead-in cables from overhead trunk routes. A knowledge of drawing office procedure is desirable.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number BCD 108/88/01.

THE GENERAL ELECTRIC COMPANY LTD., BROWN'S LANE, ALLESLEY, COVENTRY

require

DEVELOPMENT ENGINEERS
TECHNICAL ASSISTANTS
RADIO or RADAR MECHANICS

for

interesting work on Automation applied to Complex Radar and Guided Missile Systems.

Development Engineers should possess design or development experience in (a) Switching circuits, (b) Data transmission and Servo systems or (c) Radar circuits. A degree in Electrical Engineering, Physics, H.N.C., or equivalent qualifications is desirable.

Technical Assistants should preferably have experience as above. O.N.C. or equivalent is desirable.

Radio or Radar Mechanics for work on prototype equipment. Ability to work from circuit diagrams is essential.

Apply by letter, stating age and experience, to the Personnel Manager. Ref. R.G.

HER MAJESTY'S OVERSEA CIVIL SERVICE

Applications are invited for the following post:

Telecommunications Engineer
Posts and Telegraphs Department, Sierra Leone

Duties cover all general branches of telecommunications engineering, maintenance and construction of overhead and underground line plant, all types of telephone exchanges, telegraph apparatus, and point to point radio networks.

Appointment, either pensionable in salary range £964-£1,652 gross; or contract for two tours of 18-24 months each, salary range £1,042-£1,857 gross; entry point dependent on experience or war service. Gratuity £37 10s. for each three months' service, on contract appointments. Free passages for the officer and wife and free passages or an allowance of £75 for each of two children maintained outside Sierra Leone. Furnished quarters, if available, at 8½ per cent of salary, maximum £150. Seven days' leave for each month of resident service.

Candidates should be A.M.I.E.E. or have passed or be exempt from Parts A and B of the Institution's examination. Sound knowledge of theory of telecommunications engineering necessary and extensive experience of its application.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number BCD 108/15/03.

Qualified Engineer required to take charge of section concerned with research and development of Tape Recorders. Pensionable appointment. Write with full details of experience and salary required to Box No. A45/6, Strand House, Portugal Street, London, W.C.2.

NEW RESEARCH LABORATORY

IMPORTANT APPOINTMENTS

Powers-Samas Accounting Machines Ltd. (one of the Vickers Group of Companies) is expanding the resources of its Research Division for the development of electronic data processing equipment, punched-card machines and allied devices. A new Research Laboratory is under construction at Caterham, Surrey —and until its completion the staff appointed will work at existing establishments in Croydon and Crayford, Kent.

The appointments offered provide scope for both senior and junior staff. Salaries will be competitive and in accordance with qualifications and experience. Applications are invited from:—

1. Honours graduates in physics or engineering for a wide range of research and development work on electronic computors and associated equipment.
2. Engineers with Higher National Certificate for development and design work on electronic computors and associated equipment.
3. Juniors possessing evidence of the necessary scholastic and technical ability who wish to continue with studies for higher qualifications.

Applications, with details of previous experience and qualifications, should be sent to The Personnel Manager, Powers-Samas Accounting Machines Ltd., Croydon.

MULLARD RESEARCH LABORATORIES

have vacancies for graduate

ENGINEERS AND PHYSICISTS

to work in an enthusiastic and experienced research team on advanced television projects embracing a wide front of electronic techniques, including colour and semiconductors.

Apply to:

Personnel Officer,
MULLARD RESEARCH LABORATORIES,
Cross Oak Lane,
Salfords, near Redhill, Surrey,
quoting reference ERL(O).

Physicists or engineers with experience of electronic techniques, ability and enthusiasm, required for research and development work. Qualifications: honours or general degree or H.N. Cert. Some knowledge of acoustics would be of assistance but not essential.

Interesting and challenging work in expanding laboratories, permanent and with good prospects. Salaries will be paid according to qualifications, experience and ability but are based on generous scales and adequate payment during illness and pension schemes, etc., are in operation.

Apply: Personnel Manager, Kelvin & Hughes, Ltd., New North Road, Barkingside, Ilford, Essex, quoting reference RES.11/55.

COVENTRY TECHNICAL COLLEGE

Required: **Lecturer in Electronic Engineering.** Candidates should hold degree or equivalent and have had recent industrial experience preferably in Line Communication or Industrial Electronics. Commencing day by arrangement. Salary £965 × £25—£1,065. Application forms and further particulars from Director of Education, New Council Offices, Coventry.

NEW RESEARCH LABORATORY

IMPORTANT APPOINTMENTS FOR ENGINEERS

Powers-Samas Accounting Machines Ltd. (one of the Vickers Group of Companies) is expanding the resources of its Research Division for the development of electronic data processing equipment, punched-card machines and allied devices. A new Research Laboratory is under construction at Caterham, Surrey —and until its completion the staff appointed will work at existing establishments in Croydon and Crayford, Kent.

Appointments, which will be at competitive salaries, and in accordance with qualifications and experience, are offered to:—

1. Engineers with graduate or equivalent qualifications for research and development work on small complex mechanisms associated with punched card accounting systems.
2. Engineers with a sound technical background and ability to analyse complex mechanisms and to effect practical and economic improvement.

Applications, with details of experience and qualifications, should be sent to The Personnel Manager, Powers-Samas Accounting Machines Ltd., Croydon.

GOVERNMENT COMMUNICATIONS HEADQUARTERS (FOREIGN OFFICE), CHELTENHAM

Vacancies exist for Mechanical and Electrical Engineers in advanced projects in electronics, wave propagation and communication engineering. Excellent working conditions, backed by well-organized library and technical information services, specialized training and departmental assistance for higher study, considerable freedom in choice of work, unusual opportunities to gain experience of new materials, components and techniques.

Entry status dependent upon age, experience, qualifications, ability; selection by interview; good promotion prospects.

SALARIES—for men in Cheltenham:

Basic Grade Engineer—starting pay according to age up to 34. At 21, £473 10s.; at 34, £930; then by three increments to £1,055.

Main Grade Engineer—£1,055 - £40—£1,335.

Prospects of promotion to Senior Grade (£1,390 - £50—£1,571).

QUALIFICATIONS. Candidates must:

(*a*) hold university degree in physics or electrical or mechanical engineering and have at least two years' practical experience, or

(*b*) be graduates of the Institution of Electrical or Mechanical Engineers, or hold equivalent diploma.

Degree or graduateship examination should embrace telecommunications subjects including radio.

Candidates should have good communications background with knowledge of one or more following subjects:—

LF/HF, VHF and microwave techniques including transmitters, receivers and aerial distribution systems, valves, magnetic tape recorders, printing telegraph systems including VF and time division multiplex; voice communications techniques.

Two or three years' experience in electronics or telecommunications desirable, but not essential.

Appointments unestablished in the first instance but possibility of permanent established appointment by Civil Service Commission selection at a later stage. Apply to Personnel Officer (B17R), 53 Clarence Street, Cheltenham, Glos.

The Edison Swan Electric Co. Ltd.

Cosmos Works · Brimsdown · Enfield · Middlesex

has vacancies in its Research and Development Laboratories for:

1. **Circuit Development and Application Engineers** for Colour Television investigations.
2. **Circuit Development and Application Engineers** for Black and White Television development work.
3. **Engineers** for development work on Television and F.M. Amplifier problems. Previous experience in V.H.F. or F.M. required.
4. **Cathode Ray Tube Development Engineers** for development work on Colour and Black and White tubes. Previous experience on cathode ray tube development or design required.
5. **Application Engineers** for work in connection with Customer problems on Television, Radio and F.M.
6. **Engineer** for design of test equipment for Colour, Black and White Television and allied development work.
7. **Engineers** for Circuit development and Application work on Transistors.

★ ***The above applicants should have a good Engineering or Physics degree or equivalent, but vacancies also exist for candidates with H.N.C. or equivalent qualifications.***

★ ***The vacancies are a result of a large expansion in the Company's activities.***

★ ***Good salaries will be paid to suitable applicants and the positions are progressive and carry the advantages of a Pension Scheme.***

★ ***The starting salary will depend on the qualifications, experience and age of the applicants.***

Applications in writing, which will be treated with the strictest confidence, should be made to Mr. C. L. Hirshman, Chief Engineer, Applications and C.R.T.

University Laboratory engaged on research work in electronic and nucleonic fields requires additional laboratory staff. Appointments will be made in the grades Technician (£370-£20-£510), Senior Technician (£520-£20-£620), Chief Technician (£640-£20-£720), according to experience. Generous leave allowance. Pension scheme. Five-day week. Preference according to experience in instrument-making or electronics. Letters only to Registrar (N), Queen Mary College (University of London), Mile End Road, London, E.1, stating age, experience, present work.

ENGINEERS & PHYSICISTS

are required for interesting and progressive work on semi-conductor development at

The Edison Swan Electric Co. Ltd.

QUALIFICATIONS: Degree in Physics or Engineering, H.N.C. or equivalent. There are also vacancies in similar work for Technicians with O.N.C. or Inter B.Sc.

SALARIES according to experience and qualifications. Pension Scheme. Apply to:

★ ***Mr. J. Donegan, Chief Engineer, Valves,***
The Edison Swan Electric Co. Ltd., Cosmos Works, Brimsdown, Enfield, Middlesex.

o

B T-H

OPPORTUNITIES FOR ELECTRONICS ENGINEERS

Because of expanding commitments the Company wishes to increase its development engineering staff engaged on radar and other fields of activity. Applications are invited for the positions enumerated below.

1. Microwave systems engineer for interesting work concerning development of the latest techniques in waveguide systems of unusual complexity.
2. Microwave components engineer for the development of components used in complex microwave systems, including novel aerials and feeds.
3. Radar circuits engineers for the development of data extraction systems, including range and velocity processing circuits.
4. Radar transmitter engineer for the development of high power pulse and CW transmitters.
5. I.F. systems engineer for advanced development associated with pulse and Doppler radar.
6. Servo engineers for work concerning:
   (*a*) Developments in automatic machine-tool control.
   (*b*) Atomic energy projects.
7. Mechanical engineer for development work associated with large precision mechanical structures for ground radar systems.

The Company has a wide background of experience in the lines of activity mentioned and an increase in staff is required for large-scale, long-term projects. The posts are permanent and pensionable and offer ample opportunities for interesting work and professional advancement.

Qualifications: Degree in electrical engineering, physics or mechanical engineering as appropriate, and preferably at least two years' practical experience in a related field.

Applications stating age and giving details of experience and qualifications to:

The Manager, Electronics Engineering Dept.,

THE

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Member of the AEI group of companies

Inspector of Workshops required for **Broadcasting Department, Gold Coast Local Civil Service,** for one tour of 18-24 months in first instance. Consolidated salary scale £990 rising to £1,230 a year with gratuity at rate £100/£150 a year. Outfit allowance £60. Free passages. Liberal leave on full salary. Candidates must have up-to-date knowledge broadcasting equipment. Should have at least ten years' experience workshops practice in radio including five years in large broadcasting organization, preferably B.B.C., or five years in large manufacturing firm in radio industry. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41020/WJ.

TRANSISTOR AND PRINTED CIRCUIT COMPONENTS

Radio Components

The rapid development of transistors and printed circuit techniques has given rise to an interesting field for design and application of new components for these fields. Permanent, pensionable posts are offered to development engineers wishing to undertake advanced development work of this kind. The Company's laboratories, situated in the London area, are fully equipped and offer agreeable working conditions. Write to Box No. 0936, c/o *Wireless Engineer*, details of age, experience and qualifications, which will be regarded as strictly confidential.

Assistant Signals Officer required by **Sierra Leone Government Civil Aviation** for two tours each of 18/24 months. Appointment will be either (a) on contract with salary scale (including Expatriation Pay) £859 rising to £1,359 with gratuity up to £150 a year or (b) with prospect of pensionable employment with salary scale (including Expatriation Pay) £797 rising to £1,257 a year. Outfit allowance £60. Liberal leave on full salary. Free passages for officer and wife. Assistance towards cost children's passages or grant up to £150 annually for maintenance in U.K. Candidates should be experienced MF, HF, VHF, VHF/DF and ancillary equipment and should hold P.M.G. Cert. or equiv. Preference for C. & G. Cert. in Radio. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41565/WJ.

Physicist required for development duties; wide experience of electronic devices and circuit design. Applicants should have a keen interest in circuit analysis and be capable of leading a development team.

Salary in region of £900 p.a. Age between 26-36. Apply: Employment Manager, Southern Instruments Ltd., Frimley Road, Camberley, Surrey.

Electronics Engineer—an experienced engineer is required for design and development work on part of a Guided Weapon System. This is a post of great interest and responsibility; rapid promotion is possible for a man of initiative and knowledge. Candidates should have at least two years' experience and be of degree standard, although applicants without this qualification will be considered.

Please write, giving full details of age, qualifications and previous experience, quoting Ref. 73, to: The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts.

COMMERCIAL T.V.

Commercial television and F.M. broadcasting have resulted in vacancies becoming available for men interested in the development of V.H.F. tuners involving new techniques of design and manufacture. Salaries in the range of £650-£1,200 are offered to engineers with the required experience, and prospects of future advancements are good. Write, in confidence, giving full particulars of experience and qualifications to Box No. 0937, c/o *Wireless Engineer*.

ELECTRONIC RESEARCH AND DEVELOPMENT ENGINEERS AND PHYSICISTS

Applications are invited by an old-established London firm of repute for:—

Two senior posts of a highly interesting nature with scope for individual work and advancement in the field of instrumentation and automatic control and microwave developments.

A first or second class Honours Degree in Physics or Electrical Engineering would be an asset.

Applications will be treated in strict confidence.

Write to Personnel Officer, Hilger & Watts Ltd., Hilger Division, 98 St. Pancras Way, Camden Road, London, N.W.1, giving details of qualifications, experience and salary required.

OPPORTUNITIES IN THE UNITED STATES FOR ENGLISH-TRAINED ELECTRONICS ENGINEERS

The Engineering Department, Electronics Division of Westinghouse Electric Corporation, has available a number of attractive situations. Applicants must have professional standing in the Institute of Electrical Engineers or equivalent standing in the Institute of Radio Engineers.

Applicants for these positions should be over 25 years of age with at least three years' experience in design or development in one or more of the following fields:

Circuitry
Ground Radar
Communications
Computers
Filters
Antennas
Microwave Cavities and Plumbing
Missile Guidance Equipment
Navigation Aids

Plant is located in the outskirts of Baltimore, Maryland, in the beautiful Chesapeake Bay area, with splendid facilities for fishing and sailing. The mountains are but an hour and a half's drive away. Modern centrally-heated flats in suburban surroundings are readily available.

Many opportunities for advanced education and for cultural pursuits are available in the Baltimore area.

Generous relocation allowance is provided to help defray engineers' and their dependants' travel and shipping expenses.

To arrange for an interview, send résumé of education, experience and your telephone number to Department W, Westinghouse Electric International Company, 1-3 Regent Street, London, S.W.1. All replies will be treated as confidential.

EXPERIENCED RADIO TESTERS AND INSPECTORS

Required for production of communication and radio apparatus. Also instrument makers, wirers and assemblers for factory test apparatus. Apply Personnel Manager, E. K. Cole, Ltd., Ekco Works, Malmesbury, Wilts.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL,

invites applications for the following posts in its **Electronics Division.**

Ref. 519. **Senior Scientific Officer** to direct fundamental research into electronic circuit techniques with special reference to transistors and magnetic devices. Expected to supply original ideas and within wide limits free to choose line of research. Some post-graduate research experience is essential.

The laboratory is pleasantly situated and its working facilities and conditions extremely good. Publication of results is encouraged.

Ref. 517. **Scientific Officer** to assist in the direction of a group engaged on fundamental research in the same field as for the preceding post. Will be expected gradually to assume more responsibility. Publication of results is encouraged. Previous experience would be an advantage but not essential for the right type of person.

Applicants for both posts should possess a 1st or 2nd class Honours Degree in science (or equivalent).

Salary Scales:

Senior Scientific Officer: £1,105-£1,270.
Scientific Officer: £528-£948.

Contributory pension scheme. Five-day week. Excellent working conditions and generous leave allowances.

Married officers living outside the Establishment's transport area will be eligible for housing under Authority arrangements or, alternatively, substantial assistance towards legal expenses incurred in house purchase will be available.

Send POST CARD for application form to Establishment Officer, A.E.R.E., Harwell, Didcot, Berks, quoting appropriate reference.

HER MAJESTY'S OVERSEA CIVIL SERVICE

Assistant Controller of Posts and Telegraphs—Sarawak

To install and maintain all types of telecommunications equipment and systems including land-lines, cables, telephones, teleprinters, carrier, V.F.T. radio (including V.H.F.) and administration of telecommunications and postal services.

Pensionable appointment, in salary range £1,141-£2,009, plus cost of living allowance. Point of entry determined by experience. Free passages provided for officer, wife and up to three children under 18. Four days' leave for every month of resident service. Quarters provided; rental £28-£84 per annum.

Candidates should be Graduate Members of the Institution of Electrical Engineers or possess a Degree or Diploma recognized by the Institution as granting exemption from Parts A and B of its examinations. Practical experience in telecommunications is necessary.

Apply in writing to Director of Recruitment, Colonial Office, London, S.W.1, giving briefly age, qualifications and experience. Mention reference B09108/24/01.

THE UNIVERSITY OF SOUTHAMPTON

Department of Electronics

The Department of Electronics gives an advanced course at Honours Degree standard in Electronics. The course, now in its ninth year, is full-time for one academic year and the University grants a Diploma by examination to students who successfully complete the course. Entry qualification is a University degree in Physics or Electrical Engineering, or its equivalent. The next course will commence in October 1956, and application for admission should be made now to the Academic Registrar, from whom further details may now be obtained.

PLESSEY NUCLEONICS LIMITED

The Plessey Company has recently announced the formation of this new company, which is to be located in the Northampton area. Several vacancies exist for the following staff:—

1. **Senior and Junior Electronic Engineers.**
2. **Senior and Junior Design Draughtsmen.**
3. **Senior and Junior Physicists.**
4. **Senior and Junior Laboratory Staff.**
5. **Senior and Junior Site Engineers.**
6. **Production Manager and Progress Control Staff.**
7. **Workshop personnel of all grades.**
8. **Inspection personnel familiar with M.O.S. procedure.**

For senior posts, at least four years' experience in a similar position is desirable, together with appropriate qualifications. Considerable scope for promotion is offered to suitable applicants, and salaries will be in accordance with previous experience and qualifications.

Interviews can be arranged either at Northampton or at Ilford. For further details please write to the Personnel Manager, The Plessey Company Limited, Ilford, Essex, quoting reference PN/1.

Design and Development Engineers required, experienced in radio and television, for work in Jersey, Channel Islands. Salary £900-£1,200 p.a. according to qualifications and experience. Apply Box No. 0938, c/o *Wireless Engineer*.

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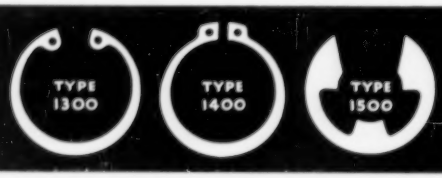

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FOCUS ON LEADERSHIP

"METALPACKS"

PAPER CONDENSERS FOR SUPER TROPICAL SERVICE

The T.C.C. 'Metalpack' range has been developed for operation in high humidities and high temperatures. Their ability to withstand variations from —40° C. to + 100° C. makes them the obvious choice of the design engineers for such applications as receivers and transmitters required to work under the most stringent conditions.

The internal construction follows the well-proved T.C.C. technique of winding non-inductively two or more layers of paper dielectric to each layer of solid aluminium foil, all impregnated under vacuum, and finally hermetically sealed in aluminium tubes. These condensers can be supplied with insulating sleeves if required.

Capacity in μF.	Wkg. Volts D.C.		Dimns. in ins.		Type Number	List Price Each
	At 70° C.	At 100° C.	L.	D.		
0·1	350	175	1½	⅝	CP45N	2/1
0·25	350	175	2	⅝	CP48N	2/8
0·5	350	175	2¼	⅝	CP47N	3/-
1·0	350	175	2¼	1	CP91N	4/-
0·05	500	350	1½	⅝	CP45S	2/1
0·1	500	350	2	⅝	CP46S	2/2
0·25	500	350	2¼	⅝	CP47S	2/10
0·5	500	350	2¼	1	CP91S	3/10
0·02	750	500	1½	⅝	CP45U	1/10
0·001	1000	650	1½	⅝	CP49W	1/10
0·002	1000	650	1½	⅝	CP49W	1/10
0·005	1000	650	1½	⅝	CP45W	1/10
0·01	1000	650	1½	⅝	CP45W	1/10
0·1	1000	650	2¼	⅝	CP47W	2/6

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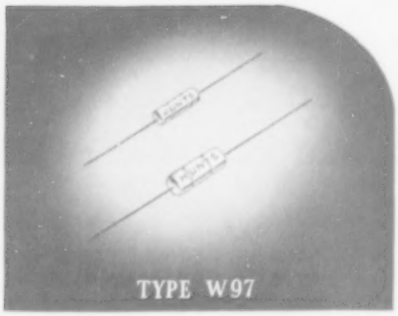

TYPE W97

HUNTS "THERMETIC" MIDGET METALLISED PAPER CAPACITORS WITH A TRUE HERMETIC SEAL

FULLY APPROVED TO JOINT SERVICES STANDARD R.C.S.136/A CATEGORY 40/100, CLASS H.1.

TEMPERATURE RANGE : — 100°C to + 100°C

The W97 capacitor, although of diminutive size, is an extraordinarily robust unit. Most miniature units are prone to weakness in end connections and general mechanical flimsiness. Such undesirable features are eliminated in the W97 by the special processes used and extreme care in manufacture.

CAPACITOR UNIT
A single metallised paper is used to wind this unit which is made possible by the use of Hunt's Patent covering the "castellated" pattern. Recent development by Hunt on a special impregnating material gives the unit remarkable brackets of operating temperature.

CASING
Hunt's patented double metal tube, sealed with the special "Thermetic" compound, provides positive closure on the casing and lead entry, ensuring positive hermetic sealing.

INSULATION OF CASING
The capacitors are supplied without an insulating medium on the case. If specially requested they can be supplied with an approved plastic sleeve which increases the dimensions by 0.07" in length and 0.03" in diameter.

TERMINATIONS
The terminations are of 24 gauge tinned phosphor bronze wire having a nominal length of 1½". Special attention is paid to the retinning of the wires after the capacitor is fully processed. Connection is made to the unit by applying copper spray to the metallising. The pigtail is soldered to this bond giving a perfect connection of exceptional strength.

INDUCTANCE
W97 "Thermetic" Midgets have a very high self resonant frequency—the following figures are quoted as a guide. 50 pF at 600 volts, which is the lowest capacitance in the range, has a self resonant frequency of 280 megacycles. At the other end of the range, 0.04 μF 200 volts, which is the maximum capacitance, it is 8.5 megacycles.

INSULATION RESISTANCE
This is measured at working voltage at a temperature of 20 C. The minimum capacitance in the range, 50 pF at 600 volts, has an insulation resistance greater than 2,000,000 megohms. The maximum capacitance in the range 0.04 μF at 200 volts, has an insulation resistance greater than 25,000 megohms. The intermediate capacitances are approximately pro rata.

POWER FACTOR
Less than 2% at 1,000 cycles per second at 20 C.

CAPACITANCE TOLERANCE
Standard ± 20%. Closer tolerances are available, for capacitances exceeding 500 pF.

TYPE W97 STANDARD RANGE

LIST NO.	CAP μF.	DIMENSIONS (inches) L.	D.
	200 volts D.C.	Wkg.	
BM7	0.002	0.610	0.135
BM8	0.004	0.610	0.135
BM13	0.004	0.500	0.180
BM9	0.005	0.610	0.135
BM12	0.005	0.500	0.180
BM13	0.01	0.500	0.180
BM14	0.02	0.610	0.180
BM15	0.03	0.610	0.260
BM16	0.04	0.610	0.260
	400 volts D.C.	Wkg.	
BM4	0.0004	0.610	0.135
BM5	0.0005	0.610	0.135
BM6	0.001	0.610	0.135
BM18	0.002	0.500	0.180
BM19	0.003	0.500	0.180
BM20	0.005	0.610	0.180
BM21	0.01	0.610	0.260
	600 volts D.C.	Wkg.	
BM25	50 pF.	0.500	0.180
BM1	0.0001	0.610	0.135
BM26	0.0001	0.500	0.180
BM2	0.0002	0.610	0.135
BM27	0.0002	0.500	0.180
BM28	0.00022	0.500	0.180
BM29	0.00025	0.500	0.180
BM3	0.0003	0.610	0.135
BM30	0.0003	0.500	0.180
BM36	0.0004	0.500	0.180
BM31	0.0005	0.500	0.180
BM32	0.001	0.500	0.180
BM33	0.002	0.610	0.260
BM34	0.003	0.610	0.260
BM35	0.004	0.610	0.260

W97 IS A 'MUST'
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